CHAMBERS'S

INFORMATION FOR THE PEOPLE.

NEW AND IMPROVED EDITION.

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EDITED BY

WILLIAM AND ROBERT CHAMBERS.

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Walter S. Burke.

PREFACE

After the lapse of eight years since the completion of the *third* and improved edition of the Information for the People, it has become necessary, from the constant and rapid advance of every branch of Science and Art, that the work should undergo a further revision. The various treatises and articles have accordingly been recast, so as to be adapted as nearly as possible to the present state of human knowledge.

Designed in an especial manner for the People, though adapted for all classes, the work will be found to comprise those subjects on which information is of the most importance; such as the more interesting branches of science—physical, mathematical, and moral; natural history, political history, geography, and literature; together with a few miscellaneous papers, which seem to be called for by peculiar circumstances affecting the British people. Thus everything is given that is requisite for a *generally well-informed man* in the less highly educated portions of society, and nothing omitted appertaining to intellectual cultivation, excepting subjects of professional or local interest. It will be understood, then, that the Information for the People is not an encyclopædia, in the comprehensive meaning of the word, but rather one embracing only the more important departments of general knowledge. The ruling object, indeed, has been to afford the means of *self-education*, and to introduce into the mind, thus liberated and expanded, a craving after still further advancement.

It may well be said of the present edition, as was said of the last, that the improvements are very considerable. The scientific treatises have, in general, been carefully remodelled, with due attention to recent discoveries. Subjects, the interest of which is past, have been omitted or greatly condensed, and others of a more enduring and important nature have taken their place. In the Indexes will be found an explanation of, or reference to, almost every subject necessary in ordinary circumstances to be known.

In one important respect—that of the pictorial illustrations and embellishments—it must be obvious, to the most cursory observation, that a very great improvement has been effected.

W. & R. C.

Edinburgh, *October* 1857.

Contents

ASTRONOMY.

ASTRONOMY teaches whatever is known of the heavenly bodies. The earth itself it regards only as one of them; viewing it, not in small portions, as we are accustomed to see it, but as an entire body, such as it would appear were we to behold it from a sufficient distance.

The subject falls naturally under two general heads:—1*st*, A *description* of the heavenly bodies—the aspect of the heavens as a whole; the distances, shapes, and magnitudes of the several bodies; the figures they describe in their motions; the way in which they are grouped into systems, &c. 2*d*, Mechanical or Physical Astronomy, or the nature of the powers or forces that carry on the heavenly motions, the laws that they observe, and the calculation of the motions from a knowledge of these laws.

GENERAL APPEARANCES OF THE HEAVENS.

When we raise our view to the sky over our heads, we find it occupied with the sun by day, and the moon and stars by night. The sun is evidently never at rest, but is either ascending upwards in the sky from the east, or else sinking towards the horizon or sky-line in the west, where his body goes out of sight. The same continual motion of rising and setting is observed in the moon; and when the stars are closely watched for any length of time, it is found that they also are constantly in a movement of the same kind. If, at the beginning of a winter-night, we fix our attention on a conspicuous star near the east point of the horizon, and continue to observe it, we shall see it rising higher and higher for about six hours; it will then begin to descend to the west, and in about six hours more it will reach the west point of the horizon, and disappear. If we commence our watch again on the following night, we may discover the same star rising at the east point at about the same hour, and going through its course of mounting, crossing, and descending the sky as before.

If we turn to some point between east and north, and notice a star just rising, we find it gradually ascending in the heavens up to a certain point; then descending to the west, and going out of sight; and finally reappearing in the east in about twenty-four hours from the time of its previous rising: but these twenty-four hours, instead of being spent one half above and the other half below the horizon, as in the former case, will be unequally divided between the presence and the absence of the star; more than twelve hours will be taken to pass from the rising to the setting, and less than twelve hours will elapse between the setting and the next rising. The further *north* the point of rising, the longer the time spent in the upper course, and the shorter the time in the under and unseen course. If we go to the north point itself, and observe a star just a little above the horizon, we shall find that it will spend the first twelve hours in ascending to its highest point in the heavens, and the next twelve in descending to the neighbourhood of the horizon; and it will not go beneath at all, but commence again to rise and describe a circle in the heavens as before; such a star, therefore, will be always in sight. In like manner, all stars in the north quarter lying within the circle described by this never-setting star, will perform their daily movement above the horizon.*

Poles, Axis.—In the inside of these circling motions we may observe a point in the sky which seems to be their common centre. A star lying in it would be perfectly at rest, and stars near it describe very small circles, or move within narrow limits. This point of rest is situated in the north quarter of the heavens, but more than half-way up from the sky-line, towards the summit. It is called the *north celestial pole*, or the *north pole of the heavens*, and is the most important point in the sky for astronomical references. No visible star is actually residing in it; but a very bright star lies near it, called for that reason the *pole-star*.

By observing the movements of stars that rise in the *south-east*, and seeing their visible paths becoming

* In the foregoing and in succeeding paragraphs, it is supposed that the stars may be seen day and night. By the naked eye no star can be seen while the sun is up, but they are all in their places nevertheless. The intense light of the sun generally makes other celestial objects invisible. With good telescopes, however, the stars may be seen in the daytime, in a clear day, except in the sun's immediate neighbourhood. From the bottom of deep wells and mines the stars in the sky overhead are seen through the day. When the moon is at a considerable distance from the sun, it may be seen when the sun is up.

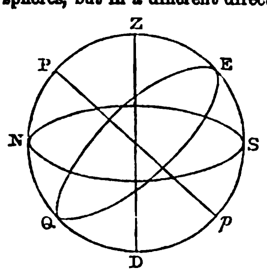
shorter and shorter, as they lie more southward, we cannot help inferring that there is a large region of stars describing circles wholly out of sight, and that there is a point beneath, which is the centre of these circles, corresponding to the centre of the northern heavens. This point is called the *south celestial pole*. An imaginary line drawn from pole to pole, or from the elevated north resting-point to the concealed south resting-point, is called the *axis of the heavens*, or the *axis of the world*. Owing to one pole being a considerable way up in the sky, and the other far down out of sight, it is evident that the great whirl of the starry sphere goes on in a *slanting* direction.

Besides the poles and axis of the heavens, there are many other imaginary points, lines, and circles, which it is convenient to suppose drawn among the stars, and which of course we can actually draw in all figures and sketches of the starry heavens. The most important of these may be here explained.

Equator, Horizon, Zenith, Meridian.—The celestial *equator*, so called because it cuts the starry sphere into two equal halves, is an imaginary circle passing round the heavens midway between the two poles. The two halves into which it divides the sphere of stars form the *northern and southern hemispheres*.

The *horizon*, or the line where the earth seems to meet the sky, makes another division of the starry sphere, into the visible hemisphere, or stars *above the horizon;* and the invisible, or stars *below the horizon.* The point of the heavens directly over our heads, or the very summit of our sky, is called the *zenith*. It is a sort of pole, or middle point, of the visible half of the heavens. The point that we should see directly beneath our feet, if the earth could be seen through, is called the *nadir*, and forms a pole and a middle point to the nether half of the heavens. These are Arabic words, meaning the extreme up and the extreme down points.

Another artificial circle supposed to be drawn in the heavens, is the *meridian*. Like the equator and the horizon, it divides the starry sphere into two equal half-spheres, but in a different direction from either of those circles. In fact, it is so drawn as to be perpendicular to both. It passes through the north point of the horizon, then upward through the north celestial pole, through the zenith, down through the south point of the horizon, through the south celestial pole beneath, and finally through the nadir: so that, in the first place, it lies north and south; and in the second place, it stands upright. Thus, if in the figure, Pp be the great axis of the heavens terminating in the north and south celestial poles, EQ the celestial equator, NS the horizon, and N and S the north and south points of it, Z the zenith, and D the nadir; then the enclosing circle of the figure NPZESpDQ is the meridian.



The leading property of the meridian is, that it determines the greatest height and the lowest depth that any star can reach. Hence when the sun or the moon passes the meridian, or lies due south, we know that it has reached its greatest height, and will immediately commence to descend. Hence, also, we can determine the meridian line in the heavens, by observing where a star is when it ceases to ascend and begins to descend; which of course gives us the direction of the north and south points, and serves the same end as the mariner's compass. The meridian also divides the upper and lower course of the stars into equal halves. The middle point between a body's rising and setting is its meridian passage.

Fixed Stars and Wanderers.—Although the general starry sphere turns round in one great mass, so that each star is always in the same place among the other stars, it was early observed that there were exceptions to the common movement; and that a small number, besides going round the sky daily, shift about among the others, so as to be sometimes near one, and sometimes near another. In opposition to these erratic or *wandering* bodies, the general multitude that kept their places were called *fixed stars*, and are used as landmarks whereby to trace the motions of the others.

The moon, for example, is soon observed to be an erratic body. One night we see it near one star, and the next night it is at a considerable distance to the east of it; even in a few hours there is a visible change of position. In the course of a month, we find it has gone through a complete circle from west to east among the stars, and come back nearly to the same place.

The sun has a similar motion, though it is slower, and also less easily marked, because his light prevents the stars from being seen at the same time. If we could see a star any night setting at the same instant as the sun, we should find that the next night it would set four minutes *before* the sun, the sun having in the meantime moved backward a short distance.

Ecliptic, Latitude, Longitude, Declination, &c.—When this motion of the sun among the stars is observed for a length of time, it is found that it forms a circuit, bringing him back, in the course of a year, to the same position. The path, however, which he travels is not exactly east and west, or parallel to the equator. If this were the case, the sun would rise and set always in the same points of the horizon. But we see that on the 21st of March, for instance, he rises exactly in the east; for the next three months the point of his rising is more and more north of east, till the 21st of June, when it begins to recede, and again reaches the east point on the 21st of September; and during the winter months it makes a similar approach to and retreat from the south. The amount of divergence either way is about a fourth of the distance between the east point and the north or south point. From this, and other appearances, it is evident that the annual path described by the sun among the stars runs slanting across the equator. This is an important circle in astronomy, and is called the *Ecliptic;* the angle which it makes with the equator is called its *obliquity*, and on this depends the variety of the seasons. Its amount is about a fourth of a quarter circle (23° 28′).

The points where the celestial equator and the ecliptic cross one another are called the equinoctial points, because the sun is in them at the equinoxes. The vernal equinoctial point is used as a fixed mark from which to measure distances on the heavens east and west, just as we measure distances east and west on the earth, or terrestrial longitude, from Greenwich.

The terms *latitude* and *longitude* have different meanings in astronomy and in geography. The latitude of a place on the earth's surface is its distance north or south of the equator; the latitude of a planet or star is its distance from the ecliptic, while its distance from the celestial equator is called *declination*. The longitude of a place is its distance east or west from the first meridian counted along the earth's equator; longitude in the heavens is distance eastward from the point Aries, measured in the direction of the ecliptic, and not in that of the equator. The distance of a heavenly body from Aries, measured in the direction of the celestial equator, is called its *right ascension*. The reason why the ecliptic is chosen to refer the latitudes and longitudes of the heavenly bodies to, is, that it is the only circle in the heavens that approaches to the permanency of the earth's equator; it maintains almost a fixed position among the stars, while the celestial equator shifts its position in the course of ages, and thus divides the starry sphere differently at different periods.

Besides the sun and moon, there are a good many other wandering stars. The ancients discovered five of

these, and gave them the name of *planets*, from the Greek word 'to wander.' The rest have been discovered since the invention of the telescope.

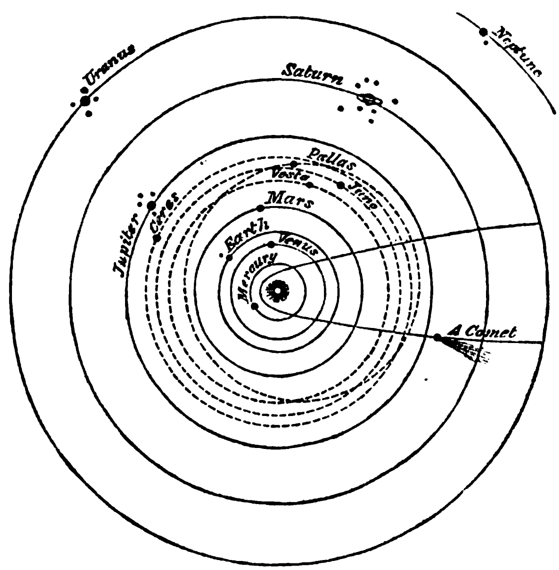
Copernican and Ptolemaic Systems.—We have hitherto spoken of the *appearances* of the heavenly bodies and their motions, without inquiring whether they are as they seem. For long, these apparent motions were considered to be real motions. The earth was believed to be—what it seems to be—a fixed station, the centre of the universe; the starry sphere was a solid shell, revolving daily with its thousand fixed fires round the central earth; while within it were a succession of crystal spheres, carrying the sun, moon, and planets, and, while partaking of the common motion from east to west, having also each a motion of its own. But as observations of the planetary motions were multiplied, it became more and more difficult to account for all the appearances in this way. At last it was found necessary altogether to change the point of view—to give up the earth as the centre of all the heavenly motions, and admit that it itself, along with the other planets, is in motion round the sun as a centre. This view, called the Copernican system, from Copernicus, its author, is now universally prevalent; the earlier is known as the Ptolemaic system, from Ptolemy, the chief ancient writer on the subject whose works we possess.

Instead of attempting to state the arguments by which the old opinions are refuted, we will proceed at once to give an outline of what is now believed to be the arrangement and constitution of the heavenly bodies. The simple way in which the Copernican system accounts for all the appearances, is the best argument in its favour.

THE SOLAR SYSTEM.

Of the heavenly bodies, those spoken of above as wanderers compose a group altogether apart, the earth being one of them. The sun, which is vastly greater than all the rest put together, forms the centre of the group; which is hence called the *solar* system (from *sol*, signifying 'sun'). Though the distances of the bodies of this group, from the central sun and from one another, are enormous when measured by ordinary terrestrial standards, they become as nothing when compared with the space that separates the whole of them from the nearest of the fixed stars. The solar system forms thus a compact inner world, cut off by an almost immeasurable chasm from the outer universe. It is with this inner world that the astronomer has chiefly to do; what is known of the fixed stars will be spoken of apart, under the head of Sidereal Astronomy.

Around the sun as a centre, the smaller bodies or *planets* wheel at different distances in paths or *orbits* of a round form, being what are called ellipses; these



The Solar System, to the orbit of Neptune.

	Diameter in Miles.	Density, Earth's being = 1.	Mass, Sun's being = 1.	Distance from Sun in Millions of Miles.	Period of Revolution in Days.	Velocity in Orbit—Miles per Hour.	Velocity of Rotation at Equator—Miles per Hour.
MERCURY,	2,950	1·20	$\frac{1}{2025810}$	37	88	110,725	370
VENUS, . .	7,800	0·92	$\frac{1}{401211}$	69	225	81,000	1,050
EARTH, .	7,912	1·00	$\frac{1}{354936}$	95	365¼	68,890	1,040
MARS, . .	4,100	0·95	$\frac{1}{2680337}$	145	687	55,812	523
PLANETOIDS,							
JUPITER, .	88,640	0·24	$\frac{1}{1048}$	494	4,332	30,203	28,128
SATURN, .	75,000	0·12	$\frac{1}{3512}$	906	10,759	22,306	22,440
URANUS, .	34,500	0·17	$\frac{1}{24900}$	1822	30,687	15,730	11,410
NEPTUNE, .	37,500	0·17	$\frac{1}{18780}$	2854	60,126	12,570	*
SUN, . .	882,000	0·26	1	*	*	*	4,564
MOON, . .	2,153	0·62	$\frac{1}{28394880}$	*	*	2,265	10

orbits lie pretty nearly in the same plane, a plane passing through the sun's centre; and the motions of the planets are, as a general rule, all in one direction—from west to east.

Some of the planets have other planets moving round them as centres—the moon, for instance, round the earth. These are called *secondary* planets, *moons*, or *satellites;* while those that move round the sun are called *primary* planets. The primary planets now known consist—1*st*, of eight larger planets, including the Earth; their names, in the order of their nearness to the sun, are—Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Herschel or Uranus, and Neptune. 2*d*, A group of small planets or *planetoids*, called sometimes also asteroids, at least forty in number. They are situated between Mars and Jupiter; and their orbits are so close and intimately connected, that the whole may be considered as making only one planet.

The satellites or moons, as yet discovered, number twenty; of which the Earth has one, Jupiter four, Saturn eight, Uranus six, and Neptune one. In addition to its moons, Saturn is attended by a luminous ring.

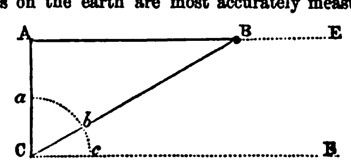
Those singular bodies called *comets* (Lat. *coma*, a lock or brush of hair) also belong, many of them at least, to the solar system. And in addition to the above luminous members of the system, it is now becoming apparent that there are multitudes of dark bodies, of various sizes, circling in the spaces between the known planets, some of which become visible to us when they accidentally enter our atmosphere as *shooting-stars* and *aërolites*.

Such is a brief inventory, as it were, of the furniture of this inner world to which we belong. Some idea may be formed of the comparative sizes and distances of the principal objects composing it, by supposing a globe of two feet diameter, placed in the centre of a level plain, to represent the sun; a grain of mustard-seed, placed on the circumference of a circle 164 feet in diameter, for Mercury; a pea, on a circle of 284 feet, for Venus; another pea, on a circle of 430 feet, for the Earth; a large pin's head, on a circle of 654 feet, for Mars; a number of minute grains of sand, on circles of from 1000 to 1200 feet, for Vesta, Ceres, Pallas, Juno, Astræa, Hebe, Iris, Metis, &c.; a moderate-sized orange, on a circle of nearly half a mile in diameter, for Jupiter; a small orange, on a circle of four-fifths of a mile in diameter, for Saturn; a small plum, on a circle of a mile and a half in diameter, for Uranus; and an ordinary plum, on a circle of two miles and a half, for Neptune. It is calculated that the united mass of the whole of the ascertained planets is not above a 600th part of the mass of the sun.

The figure on the preceding page represents the relative positions of the chief planetary orbits, including those of the four earliest discovered planetoids. Appended are tables of the diameters, distances, and other numerical particulars of the several bodies.

Astronomical Mensuration.—Though it would be inconsistent with the scope of the present sketch to describe minutely the processes by which the above numbers are found, it is necessary to give a general idea of the methods followed, that the reader may be able to conceive the possibility of measuring and weighing objects so completely beyond our reach.

The astronomer finds the distance between objects, not by measuring lines, but by measuring *angles*. Even distances on the earth are most accurately measured in

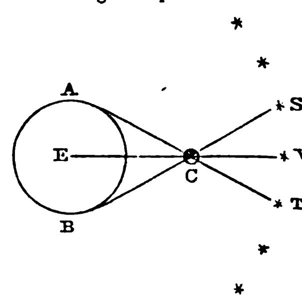


this way, as in trigonometrical surveying. Suppose that an observer at A wishes to ascertain the distance of an inaccessible object at B; it could never be found by looking at it from A alone. He chooses another station, C, to which he has access, in a direction perpendicular to the direction of B, and at a convenient distance, say 100 yards. If the object looked at from A lay directly east, it will no longer be east when looked at from C; its direction is now CB, not CE, and the difference of direction is seen in the greater or less wideness of the opening between those two lines, or in the *angle* BCE, as it is called.

To ascertain the exact comparative wideness or size of angles, a circle is described about the point C, where the lines meet, and the lines intercept a greater or less portion or arc of it. As the circle is supposed divided into 360 equal parts, called degrees, if the arc *cb*, for example, is the twelfth part of the whole circle, it will contain 30°; 30°, therefore, is the measure of the angle BCE, and also of the angle ABC, which, as is evident to sight, is equal to BCE. It is clear, too, that the arc *ac* being the fourth part of the whole circle, and thus containing 90°, the arc *ab*, or the angle ACB, will contain 60°.

By considering the figure, it will be seen that the more distant B is, the larger must be the angle ACB, and the smaller must be ABC. For every size of either of these angles there is a certain fixed length of AB; and trigonometry teaches, from knowing the *base* AC and either of them, to find the length of AB. Everything depends on measuring the angles of direction, or the angular distances, accurately. Degrees are divided each into 60 parts, called *minutes*, and these again into 60 parts, called *seconds;* and astronomical instruments are now so delicate that a difference of direction of one second can be measured.

The difference of direction in which a body is seen when viewed from two places at a distance from one another, is called by astronomers *parallax*, or displacement. The annexed figure represents the effect of parallax on a heavenly body C. V is its *true* place, or place in the sky as seen from the earth's centre; T is its place as seen from the surface at A, and the arc TV, or the angle ACE, is the amount of the horizontal parallax.



The distances of the heavenly bodies, even the nearest of them, are so great, that even when the two stations are taken as wide apart as possible—that is, from the opposite sides of the earth, where the distance between them is equal to the earth's diameter, or nearly 8000 miles—the angle of parallax ACB, or the displacement on the sky TS, is very small. In the case of the moon, the nearest of the heavenly bodies, it is nearly two degrees; and by means of it the distance of the moon is found to be about 237,000 miles, or about sixty times the half-diameter or radius of the earth. When the sun is observed from opposite sides of the earth, he suffers a displacement of only seventeen seconds of a degree. This corresponds to a distance of about 95,000,000 miles. On so small an angle, a slight error of observation materially affects the result; and therefore other expedients were had recourse to, to determine the sun's distance with greater certainty and exactness. When the distance of the earth from the sun was once known, a new and vastly extended base was obtained for the trigonometrical survey of the heavens. As the earth travels in its annual circuit round the sun at the distance of 95,000,000 miles, by observing a heavenly body at two different times, at an interval of

six months, we in effect observe it from two stations removed from each other by the whole breadth of the earth's orbit, or nearly 200,000,000 miles. The displacement produced in this way is called *annual parallax*. Even this enormous base becomes as nothing when applied to measure the distances of the fixed stars; by far the greater number shewing no sensible parallax.

Knowing the distances, we can find the real sizes of bodies from their apparent size, or from their dimensions taken by an angular instrument. If an object be a mile off, and if its breadth make an angle of 1° at that distance, its real size is determined by these two quantities. Thus the *moon* being about 237,000 miles from the earth, and having an angular breadth in the sky of somewhat more than half a degree, its actual breadth must be about 2000 miles. The accurate estimate is 2153 miles—rather more than a fourth of the diameter of the earth. The *sun* has almost the same apparent size in the sky as the moon; but being at about 400 times the distance of the moon, it must have 400 times the breadth of the moon to appear equally large. In fact, the sun's diameter is more than 111 times that of the earth. The diameters of the planets are determined in the same way.

The solid contents or *volumes* of the several bodies are found from their diameters, by a simple rule of geometry. To state the number of cubic miles that each contains, gives little real information, the important thing being their relative magnitudes. Now, it is important to bear in mind that the magnitudes or bulks are not in the simple proportion of the diameters, but as the *cubes* of the diameters. Thus, the diameter of the sun being upwards of 111 times that of the earth, his volume or bulk will be 1,400,000 (111 cubed) times greater.

To speak of *weighing* such stupendous masses as the sun, moon, and stars, seems at first sight extravagant; yet it is by no means one of the most difficult problems, as will be explained under Mechanical Astronomy.

Diameter of the Earth.—In measuring the distances of the heavenly bodies, the diameter of the earth is taken as a known base to start from; but how is this got at? If at any place we observe the height of a star on the meridian—say the pole-star—and after travelling directly north for a considerable distance, observe the height of the same star, it will be found to be greater. This arises from the round form of the earth; and it is easily shewn that if the star has risen one degree higher in the heavens, the observer must have moved north one degree. We are thus enabled to fix two stations on a meridian, the distance between which shall be exactly one degree, or the $\frac{1}{360}$th part of the whole circle or circumference of the earth. When the length of such a line is measured, it is found to be a little less than seventy English miles. This, multiplied by 360, gives the whole circumference in round numbers at 25,000 miles, and the diameter at 8000.

SEPARATE MEMBERS OF THE SYSTEM.

The Sun (☉).—The apparent or angular breadth of the sun is, on an average, 32′ 3″; owing to its being nearer to us at one time than at another, the apparent magnitude varies about half a minute either way. The real diameter of the sun, as already stated, is 111 times that of the earth, and its volume 1,400,000 times as great. It may help to form a vivid conception of this comparative vastness, to conceive the sun a hollow sphere, and the earth placed at the centre; in this position, the moon circling round the earth at the distance of 240,000 miles, would be still 200,000 miles from the circumference of the sphere.

That the sun is a ball or globe is evident from its always appearing round, while we know, at the same time, that it turns or rotates on an axis. The fact of its rotation is inferred from dark *spots* which are seen at times on its surface: they are observed to move all at the same rate, and in the same direction across the surface, to disappear for a time, and then come again into view at the other side; and by this means the period of rotation is ascertained to be 25¼ days.

A careful study of these spots has led to some very probable conjectures as to the nature or physical constitution of the sun. A solar spot presents the appearance of an intensely black irregular patch, surrounded by a less dark fringe. They appear and disappear very irregularly, some lasting only a day, others for weeks and even months. Sometimes no spots are to be seen for a long time, at other times they appear in profusion. But it is observable that they are confined to two broad zones, parallel to the sun's equator, and corresponding in some degree to the temperate zones on the earth. Individual spots have been seen to attain the enormous breadth of 45,000 miles, covering an area of five times the surface of the earth.

Judging from all the appearances, it is held highly probable that the nucleus of the sun is a dark solid globe, and that this is surrounded by two gaseous coatings or layers of some depth, the lower one being non-luminous, like our atmosphere, and the upper being a luminous gas or flame. An opening, then, in this upper luminous stratum, like a break in a layer of clouds, would present the appearance of a dark spot. The openings might be occasioned by any commotion in the gaseous coverings of the sun similar to our tornadoes or hurricanes. As to the source of the sun's *heat*, we can only conjecture. It is difficult to suppose it to be combustion of any kind, and electrical currents have been suggested as the cause.

From appearances attending total eclipses of the sun, and other phenomena, it is concluded that there is a third gaseous atmosphere, above the luminous matter. It is imperfectly transparent and cloudy, and seems to extend many thousand miles in height. The rose-coloured projections seen during eclipses are believed to be clouds in this atmosphere.

Some hold it not improbable that the sun may be inhabited. The gaseous stratum, which is the source of light and heat, appears to be at a great elevation above the solid nucleus; and the non-luminous stratum or atmosphere that intervenes may be of a nature to temper the rays, and render their intensity consistent with organic life.

Mercury (☿) and *Venus* (♀), the two members of the system next to the central body, are called *inferior* planets, from their orbits being within that of the earth. Owing to their position, they can never appear at any great distance or *elongation* from the sun. Mercury, in fact, even at its greatest elongation, sets long before the end of twilight, or if west of the sun, does not rise till the dawn has begun; so that in our latitude and cloudy climate, it is rarely seen with the naked eye. Venus attains more than twice the elongation of Mercury, and is seen long after night has fairly set in, or before the morning twilight. Both inferior planets go through *phases* like the moon, and when seen through a telescope, have a crescent or a gibbous shape. They are never seen when full, or when new, being then near the sun. Venus is the most conspicuous of the heavenly bodies, next to the sun and moon; when it rises before the sun, it is called the *Morning Star*—the Lucifer of the ancients; and when it sets after the sun, it is the *Evening Star* or Hesperus.

Telescopic observations of Mercury and Venus are very difficult, owing to the intense brilliancy of the surface. It is concluded that we do not see the real surface, but only their cloudy atmospheres. Even the times of their rotation on their axis cannot, according to Sir J. Herschel, be held as accurately determined; still less the height of the mountains, which some observers have fancied they saw. Others think it

satisfactorily demonstrated that Venus rotates in 23 hours 15 minutes. The dense clouds which load the atmospheres of those planets, may mitigate the intense glare of the sun, and render them habitable by organised beings.

The *Earth* (⊕) is the third planet in order from the sun, and closely resembles Venus. Its diameter in round numbers is, as already stated, 8000 miles. But the earth is not a perfect sphere; it does not measure the same in all directions, but has its axis, or the diameter on which it rotates, shorter than its diameter at the equator. This is a general law in all planets, the cause of which will be explained under the head of Mechanical Astronomy. The earth, then, is flattened at the poles, and its shape is called by astronomers an oblate spheroid. If it were cut in two, by a plane passing through the two poles, the section would be, not a circle, but an oval, or *ellipse;* and the excess of the *equatorial* diameter over the *polar* diameter is called the *ellipticity* of the spheroid. The ellipticity of the earth is found to be $\frac{1}{300}$, or the equatorial diameter exceeds the polar by $\frac{1}{300}$th of its length.

This was determined in two ways: by measuring degrees of the meridian at different latitudes; and by measuring the variation in the force of gravity, between the equator and the poles. In the ellipse formed by a section of the earth in the direction of a meridian, the curvature or bending is sharper towards the ends, or near the equator, than towards the poles. The ends of the ellipse are portions of a smaller circle, as it were, than the middle parts; and a degree of the smaller circle will be shorter than one of the longer. The lengths of a degree in various latitudes, from the equator, to upwards of 60° north, have been measured with great accuracy, and been found to increase towards the pole, and from these the lengths of the two diameters have been calculated. The polar diameter, omitting fractions, is 7899 miles, the equatorial 7925; the difference is thus 26 miles, and the mean diameter 7912 miles.

The variation of gravity at different places on the earth's surface, as measured by the vibrations of the pendulum (see NATURAL PHILOSOPHY), gives the same results, and thus the two methods confirm one another.

To ascertain the density of the earth, is a delicate problem, to be more particularly described under the head of Mechanical Astronomy. It is found to be from 5½ to 6 times that of water. The densities of the other heavenly bodies are always given as compared with that of the earth, which is stated as 1. The motions of the earth, and the appearances caused by them, as well as the motions of its accompanying satellite, the moon, will be described under separate heads.

Mars (♂), the fourth in order, is the nearest to us of the *superior* planets. Its volume is less than the seventh part of that of the earth, and its mass nearly in the same ratio. By means of spots on its surface, it is distinctly ascertained to turn on its axis in 24 hours 37 minutes, the axis being inclined to the plane of its orbit at an angle of 28° 27′. Its days, then, are nearly the same as ours; and its year, which contains 668 Martial days, is varied by seasons like the terrestrial year. Mars has a reddish aspect; permanent spots and markings are seen by the telescope, which must therefore be on the solid surface. Around each pole is a region of dazzling white, conjectured to be snow, from the circumstance that the white circle is observed to diminish during the summer of the hemisphere in which it lies, and increase during the winter, exactly as the snows of the terrestrial polar regions do.

The *planetoids* or *small planets* circulate in a region lying between the orbits of Mars and Jupiter, but on the whole nearer to the former. They form a distinct group of themselves, and the region of their orbits may be considered as constituting a zone of separation dividing the eight chief planets into two groups—four *interior* planets (Mercury, Venus, the Earth, Mars), and four *exterior* (Jupiter, Saturn, Uranus, Neptune), which two groups present several points of contrast. It is only recently that the existence of the small planets has become known, the first, Ceres, having been discovered in 1801. From observing, however, that there is a sort of law in the distances at which the planets generally succeed one another, it had long been conjectured that a planet or planets might yet be discovered in the interval between Mars and Jupiter, which formed a break, as it were, in the regularity of the progression. The discovery of Ceres by Piazzi at Palermo in Sicily (Jan. 1, 1801), was followed by that of Pallas (March 28, 1802) and Vesta (March 29, 1807), by Olbers, at Bremen, and of Juno (Sept. 1, 1804), by Harding, at Lilienthal, near Bremen. A period of thirty-eight years followed without any addition being made to the group. In the meantime, a multitude of observers had laboured with untiring industry in mapping down the smaller stars in the region of the zodiac, so as to make it more easy to distinguish between a moving body and a fixed. The fruit of these labours began at length to appear in the discovery of Astræa (Dec. 8, 1845), and that of Hebe (July 1, 1847), by Professor Hencke, in Prussia. The observations of Mr Hind, in London, De Gasparis at Naples, and other astronomers, have since raised the number of the asteroids to above forty, with every prospect of further additions.

In addition to their comparative smallness, the planets of this group are distinguished by their orbits being much more elliptical or elongated than those of the others, and also having a greater inclination—that is, rising and sinking much further from the plane of the ecliptic. The inclination of Pallas is as much as 34° 37′. It is difficult to determine the diameters of the telescopic planets with any certainty. The largest is held not to exceed 600 miles in diameter, and the great body of them to be under 100 miles.

The distances of the small planets from the sun mostly range between two and three times that of the earth; and in the case of several of them, the difference of distance is very small. Besides being unusually near to one another, their orbits are singularly interlaced. 'The strongest evidence,' says one astronomer, 'of the intimate connection of the whole group of small planets appears to be, that if the orbits are supposed to be represented materially as hoops, they will hang together in such a manner, that the whole group may be suspended by any given one.' From these and other observed facts, cosmogonists presume that the matter which in other cases has gone to form one planet of the first rank, has in their case been separated into several parts, assuming various but connected orbits. Olbers boldly conjectured that a single primitive planet had, by explosion or other natural force, been shattered to pieces; and an American astronomer, Mr Kirkwood, has undertaken to restore the exploded primitive planet from the fragments, as the animals of the primitive earth are restored from their fossil remains.

Jupiter (♃).—The four planets constituting the *outer* group are on a much more stupendous scale than the inner; hence they are called by some *major* planets; while the inner group are called *terrestrial* planets, from their many analogies to the earth. The first and largest of all is Jupiter. The diameter of Jupiter being upwards of eleven times that of the earth, his volume is 1400 times the volume of the earth. In its orbit this enormous globe moves at the rate of 500 miles a minute—a speed sixty times greater than that of a cannon-ball, and yet it takes nearly twelve of our years to accomplish its circuit! To the inhabitants of Jupiter the sun must appear less than one-fifth of the breadth he presents to us. By means of permanent marks, it is ascertained that the planet rotates on an axis inclined to its orbit at the small angle of 3° 6′, and in the short space of 9 hours 55 minutes. This makes the rotary velocity of Jupiter's

surface twenty-seven times greater than that of the earth. Viewed through a telescope, Jupiter appears traversed by dark lines, or belts, which are supposed to be parts of the body of the planet, seen through openings in a bright cloudy atmosphere.

Jupiter is attended by four satellites, which revolve round it as the moon revolves round the earth, but in much shorter periods—the nearest requiring only forty-two hours. One of these satellites is of the same size as our moon; the others, larger. Their density is very small, one of them being twice as light as cork; so that the mass of the whole is only a 6000th part of that of Jupiter itself. Seen from his first satellite, Jupiter must present a surface more than 300 times greater than that of the full-moon. These satellites frequently eclipse the sun to Jupiter; they are also eclipsed by the primary planet.

The satellites of Jupiter were discovered by Galileo, being among the first results of the invention of the telescope. They have been of great use in several astronomical calculations of importance, particularly in suggesting the theory of the gradual propagation of light. It having been observed that their eclipses always took place sooner than was to be expected when the earth was near Jupiter, and later when it was at the greatest distance, an astronomer solved the difficulty by supposing that light required some time to travel—a conjecture which was afterwards confirmed by other observations.

Saturn (♄) with its ring, or rather rings, and eight moons, is the most remarkable member of the solar system. Its volume is about 900 times that of the earth; but its density being only a little more than half that of water, its mass is 100 times that of the earth. It turns on its axis in 10 hours 29 minutes, and its year is about 29½ of our years.

The singular appendage called the ring of Saturn surrounds the body of the planet in the plane of its equator. It is thin and broad like the rim of a spinning-wheel, and is always seen with its edge presented more or less directly towards us. It is luminous with the sun's light, and casts a shadow on the surface of the planet. The distance of the inner edge from the planet is calculated at about 19,000 miles; its entire breadth from the inner to the outer edge is 29,538; the thickness is about 250 miles. In certain positions of the planet, we can see its surface at a considerable angle, and the openings or loops which it forms at the sides of the planet. At other times, we see its dark side, or only its edge. From observations made upon it in favourable circumstances, it is found to be divided into two independent and concentric rings of unequal breadth, the outer being the smaller. The interval, which appears as a dark line, is about 1800 miles broad. In 1850, a third, feebly luminous and darker ring, was discovered between the planet and what had hitherto been called the inner ring, from which it is separated by a black line. The rings rotate in their common plane in the same time, or nearly so, as the planet, and the centrifugal force thus generated prevents them from collapsing and falling in upon the planet. Some astronomers are of opinion that 'the ring consists of a stream or streams of a fluid rather denser than water flowing round the primary.'

The eight satellites of Saturn revolve around it, on the exterior of the ring, and almost all of them in nearly the same plane. They are so small as not to be visible without a powerful telescope. The revolutions of these satellites range from one to seventy-nine days. The distance of Saturn reduces the light and heat derived directly from the sun to the ninetieth part of their intensity at the earth's surface; on the other hand, the spectacle of the heavens arising from the reflected light of the rings and moons must be magnificent and varied.

Uranus (♅) is invisible to the naked eye, and was discovered by Sir William Herschel in 1781. Its distance from the sun is nineteen times that of the earth, requiring two hours and a half for the sun's light to reach it. Its volume is eighty-two times that of the earth. Its period of rotation is stated at 9 hours 30 minutes; while others hold that nothing is known as to its rotation, or to its atmosphere and surface.

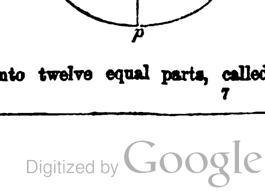
Uranus is attended by at least four satellites, probably by five or six. In two respects, these satellites are quite singular: their orbits are nearly perpendicular to the plane of the ecliptic; and their motions in the orbits are *retrograde*—that is, from east to west, instead of being from west to east, like those of all other planets both primary and secondary.

The discovery of *Neptune* (♆) is one of the greatest triumphs of scientific astronomy. From irregularities observed in the motion of the planet Uranus, it had been conjectured that some disturbing cause, not yet discovered, was acting upon it. Two astronomers, M. Le Verrier, in Paris, and Mr J. C. Adams of Cambridge, independently of one another, calculated where this disturbing cause must be situated. The results of Le Verrier were first made public; and Dr Galle of Berlin detected the new planet at the first search, September 23, 1846, within two diameters of the moon's disk from the place assigned for it by Le Verrier. The distance of Neptune from the sun is thirty times that of the earth. Its year is nearly 165 of ours (60,126·7 days); and it has been ascertained to be attended by at least one satellite, whose orbit is inclined to the ecliptic at the large angle of 34°.

UNIFORMITIES OR LAWS IN THE SOLAR SYSTEM.

These details of the movements, magnitudes, distances, &c., of the separate members of the solar system, are apt at first sight to appear a mass of unconnected facts, without any discernible plan; but more attentively considered, they display in several respects order and law. The regular way in which the distances between the planets go on increasing, has already been adverted to. The distances of the orbits of the successive planets from that of Mercury form a progression, each being nearly double of the preceding, as may be seen by inspecting the table of distances from the sun. Thus, Venus is distant from Mercury 32,000,000 miles; the Earth, 58,000,000; Mars, 108,000,000, &c. Before the discovery of the planetoids, there was a striking break in this progression between Mars and Jupiter, which first suggested the idea of a missing planet. Beyond Jupiter it is continued pretty closely, except in the case of Neptune, whose actual distance is much less than the progression requires. Astronomers now regard this remarkable numerical harmony as rather a casual coincidence than a real law.

A more important uniformity among the planets is, that their orbits lie all nearly in one plane. If we take the plane of the earth's orbit, which is the same as that of the ecliptic, as a standard of reference, and suppose it represented by a ring held horizontally with the sun in its centre, then the other orbits will be represented by other rings, two within, and the others without, held so as also to have the sun in the centre, and (with the exception of a few of the planetoids) never rising above or sinking below the level of the earth's ring more than a very few degrees. In consequence of this arrangement, the motions of the planets, as seen from the earth, are confined to a narrow zone of the heavens, extending about 8° on each side of the ecliptic (RT in the fig.). This circular belt, called the *Zodiac*, was from the earliest times divided into twelve equal parts, called



signs, containing, of course, 30° each. These signs received each a particular name, from the groups of stars or constellations in them having a fancied resemblance to certain figures, chiefly of animals. The names of the signs, with the symbols by which they are usually represented, are as follows :—

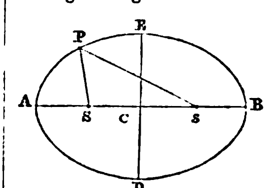
♈ Aries, the Ram.	♎ Libra, the Balance.
♉ Taurus, the Bull.	♏ Scorpio, the Scorpion.
♊ Gemini, the Twins.	♐ Sagittarius, the Archer.
♋ Cancer, the Crab.	♑ Capricornus, the Goat.
♌ Leo, the Lion.	♒ Aquarius, the Water-bearer.
♍ Virgo, the Virgin.	♓ Pisces, the Fishes.

This division of the zodiac affords a ready means of pointing out the place of a planet (*c*), or of the sun (S) or moon, at any particular time, by telling in what sign it is.

Besides moving nearly in one plane, the planets move all in one direction—namely, from west to east. The same law prevails among the satellites, with the remarkable exception of those of Uranus, which have a *retrograde* movement, or from east to west.

But the grand uniformities of the solar system are those discovered by the celebrated astronomer Kepler, and known as 'Kepler's Laws.' Kepler merely deduced them as matters of fact from the observations of himself and others; it remained for Newton to discover their cause. One of these laws respects the exact form of the paths in which the planets move. The ancients, from some imaginary perfection which they attributed to the circle, had taken it for granted that all celestial movements must be circular; Kepler made the important discovery that this is an error, and that the planetary orbits are *ellipses*.

The ellipse is an important figure in astronomy; for not only are the planetary orbits ellipses, but the planets themselves have an elliptical shape, as we saw when speaking of the form of the earth. There is a ready practical way of describing an ellipse, which at the same time gives a good sensible notion of its nature. If the ends of a thread are fastened by pins to two points S and *s*, at a distance apart less than the length of the thread, and if the point of a pencil P, is put into the loop of the thread, and moved round so as to keep it stretched, the pencil will trace an ellipse.



The two points S and *s* are called the *foci* of the ellipse; AB is the major or transverse axis, C the centre; and SC, the distance of the focus from the centre, is the *eccentricity*. With the same length of thread, a variety of ellipses may be described, by altering the distance between the points S and *s*. The nearer they are brought to each other, the rounder does the figure become; and when they come together, it forms a perfect circle. In the planetary orbits, the sun is always in the focus S, and therefore the planet is at different distances from the sun in different parts of its orbit. When it is at A, the nearest point, it is said to be in *perihelion;* and when at B, in *aphelion*. SE is the mean distance, and is equal to AC. The planetary orbits differ very little from circles, or have very little eccentricity. The earth's orbit, if accurately represented on paper, could not be distinguished from a circle by the eye; the difference between the greatest and least distances from the sun is about the thirtieth part of the mean distance.

Another of Kepler's laws connects the change of a planet's distance from the sun, with the speed of its motion: when the distance *increases*, the speed *diminishes;* and at the least distance we find the greatest speed. The calculation, however, must be made by squaring the distance. Thus, if the distance increased from 9 to 10, the velocity would diminish at the rate of 100 to 81. If, therefore, we know the change of velocity, we shall be saved from *observing*—for we can *calculate*—the change of distance. This law is called the law of *equal areas*, because the areas swept over by the line joining the sun and planet are equal in equal times. This line is termed the *Radius Vector*.

The two laws already noticed refer to the motions of a single planet; the third law shews a relation between the motions of all the planets, or all the bodies that revolve round the same centre. It is, that *the squares of the periodic times of any two planets are to each other as the cubes of their mean distances from the sun;* that is, if there be two planets, and one further off than the other, the near planet will perform its revolution quicker than the other, and according to a fixed proportion. Thus, the periodic times of the earth and Mars are 365¼ and 687 days, and their distances as 100 to 152⅓; and by Kepler's law the square of 365¼ is to the square of 687 as the cube of 100 to the cube of 152⅓; which, on making the calculation, will be found to be the case. This law goes still further to shorten the labour of observation, and increase the knowledge derivable from what is observed. If a new planet is discovered, the astronomer has only to observe its distance; this once known, the time of revolution can be determined, without waiting till we see it go actually round the heavens. This third law gives a sort of family relationship to all the bodies of the solar system, and shews that though they move widely apart from each other, yet their connection with a common centre maintains harmonious relations throughout the whole. The same three laws apply to the revolutions of satellites about their primaries.

DIURNAL AND ANNUAL MOTIONS OF THE EARTH.

The earth, like all the other planets, has two motions: it whirls round its axis once a day; and while doing so, it is all the while travelling bodily through space in a wide circuit round the sun, which it accomplishes in a year. The first is called a motion of *rotation*, the second of *translation*. The two combined give rise to the vicissitudes of day and night and of the seasons.

The circumference of the earth being 25,000 miles, any spot at the equator, in order to go round in twenty-four hours, must move upwards of 1000 miles an hour. This velocity decreases towards the poles, because the circles to be described become less; but in Great Britain it is still nearly 600 miles an hour. It is difficult, at first sight, to reconcile this notion with the impression we have of the 'firm earth,' which is to us the very emblem of fixedness and rest. But in order to learn to distrust our feelings in the matter, we have only to reflect how easily they are imposed upon in many familiar instances of a similar kind. While looking at surrounding objects from the deck of a smooth-going vessel or the window of a railway-carriage, the objects seem to be fleeting past, and we ourselves to be at rest. It is in this way that the swift, but smooth and noiseless whirl which carries the earth's surface and its inhabitants eastward, makes the starry vault seem to flit past the eyes of these inhabitants towards the west.

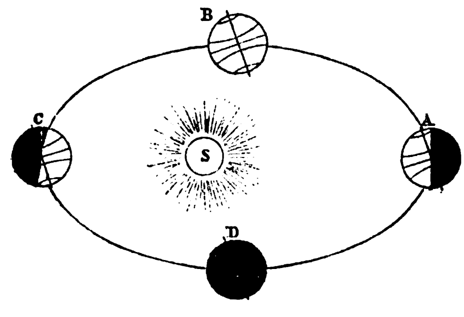
It is the earth's rotation that causes the vicissitude of day and night. The earth being a globe, only one-half of it can be in the sun's light at once; to that half it is day, while the other half is in its own shadow, or in night. But by the earth's rotation, the several portions of the surface have each their turn of light and of darkness. This happens because the position of the earth is such that the equator is on the whole presented towards the sun; had either pole been towards the sun, that hemisphere would have revolved in continual light, the other in continual darkness.

Length of a Day.—One complete rotation of the earth does not make a day, in the usual sense. If the time is noted when a particular fixed star is exactly south or on the meridian, when the same star comes again to the meridian the next day, the earth has made exactly

one rotation, and the time that has elapsed is called a *sidereal day*. This portion of time is always of the same length; for the motion of the earth on its axis is strictly uniform, and is, in fact, the only strictly uniform motion that nature presents us with. Sidereal time, or star-time, from its unvarying uniformity, is much used by astronomers. But the passage of a star across the meridian is not a conspicuous enough event for regulating the movements of men in general. It is not a complete rotation of the earth, but a complete alternation of light and darkness that constitutes their day. This, which is called the *civil* or the *solar* day, is measured between two meridian passages of the sun, and is about four minutes longer than the sidereal day. The cause of the greater length is this: When the earth has made one complete turn, so as to bring the meridian of the place to the same position among the fixed stars as when it was noon the day before, the sun has in the meantime moved eastward nearly one degree among the stars, and it takes the earth about four minutes more to move round so as to overtake him. If this eastward motion of the sun were uniform, the length of the solar day would be as simple and as easily determined as that of the sidereal. But the ecliptic or sun's path crosses the earth's equator, and is therefore more oblique to the direction of the earth's rotation at one time than another; and besides, as the earth moves in her orbit with varying speed, the rate of the sun's apparent motion in the ecliptic, which is caused by that of the earth, must also vary. The consequence is, that the length of the solar day is constantly fluctuating; and to get a fixed measure of solar time, astronomers have to imagine a sun moving uniformly in the celestial equator, and completing its circuit in the same time as the real sun. The time marked by this imaginary sun is called *mean solar time;* when the imaginary sun is on the meridian, it is *mean noon;* when the real sun is on the meridian, it is *apparent* noon. It is obvious that a sun-dial must shew apparent time, while clocks and watches keep mean time. Only in four days of the year do these two kinds of time coincide. In the intervals, the sun is always either too fast or too slow; and the difference is called *the equation of time*, because, when added to or subtracted from apparent time, it makes it equal to mean time. The mean solar day is divided into twenty-four hours, the hours into minutes and seconds. A sidereal day, we have seen, is shorter; its exact length is 23 hours, 56 minutes, 4 seconds of mean solar or common time. Astronomers divide the sidereal day also into twenty-four hours, which are of course shorter than common hours. In the course of a civil year of 365 days, the earth turns on its axis 366 times, or there are 366 sidereal days.

The earth, then, gliding noiselessly and steadily round on its axis, is the great time-keeper, and the heavenly bodies are the pointers or indices by which we note its progress. The art of reading off the hour of the day from the heavenly bodies is necessary in the important problem of *finding the longitude* at sea. (See MARITIME CONVEYANCE.)

The Seasons.—The way in which the earth's annual motion round the sun produces the alternations of the seasons, may be sensibly illustrated as follows:—Having placed a lamp or candle in the middle of a round table, to represent the sun, take a round ball with a straight rod passing through its centre, to represent the earth with its axis. Holding the globe over the north edge of the table (as at C, in the figure), on a level with the light, place the axis, not quite upright, but leaning northwards at an angle of 23° 28′ from the perpendicular; and the upper end of the rod being considered the north pole, we have the position of the earth with respect to the sun on the 21st of December, or winter solstice. By turning the ball on its axis, it will be seen that in the northern hemisphere any spot is longer in darkness than in light; while a considerable space round the pole never comes into the light at all, and has thus perpetual night as well as winter. In the southern hemisphere, again, every place is longer in light than in darkness, and a space round the pole has perpetual day.



In carrying the ball round the edge of the table to represent the earth's translation round the sun, care must be taken to keep the axis always *parallel to its original position*—that is, always with the same slope, and that slope pointing to the north. As we recede from C, the difference of illumination of the two hemispheres diminishes, till at B, one quarter round, the rays fall directly on the equator and reach to both poles, and as the earth turns, every spot on its surface, is as long in light as in darkness. This is the position at the *vernal* equinox on the 21st of March, when the days and nights are equal all over the earth. On the 21st of June, the summer solstice, the position is that represented at A, and corresponds to that at C, except that it is now the northern hemisphere that enjoys most of the sun's rays, or has summer, while the southern hemisphere is in winter. In moving through the remaining half of the circuit, the ball comes into a position at D similar to that at B, and representing the *autumnal equinox* on the 21st of September.

The earth is in perihelion on the 1st of January; it is then about 3,000,000 miles nearer to the sun than on the 1st of July; the sun's disk is slightly broader, and we might expect this circumstance to mitigate the severity of our winter, and to add to the heat of summer in southern latitudes. But owing to the action of the law already given, by which the velocity of a planet increases with its nearness to the sun, the earth passes over the perihelion half of its orbit in less time than over the other half, and thus the effects of greater proximity are counteracted.

It is this real motion of the earth in its orbit that causes the apparent motion of the sun in the ecliptic already described. If we conceive a wide circle, described outside the orbit, to represent the sphere of the fixed stars, when the earth is at A, the sun will appear to be at a point in this circle beyond C; and as the earth moves towards D, the sun will seem to travel along the outer circle in the direction of B. When the earth is at B, and the sun's rays fall perpendicular upon its equator, the sun will appear to be in the celestial equator, or in that point of the ecliptic where it crosses the equator, which is called the *equinoctial* point Aries. The earth's orbit, then, and the circle of the ecliptic, are in the same plane. If we conceive the orbit to be a solid ring or hoop, a sheet of parchment stretched over it like a drum-head would represent the plane of the orbit; and this sheet, extended straight in all directions to the concave of the fixed stars, would meet that concave in the circle of the ecliptic. It is to this plane that the orbits of all the other planets are referred; they cross it at small angles, and the points of crossing are called *nodes*.

A year, in the usual sense of the term, is the time

that the sun takes to move from either equinox back to the same equinox, or from either tropic back to the same tropic. This embraces a complete circle of the seasons, and brings the earth into the same position with respect to the sun; hence it is called a solar, equinoctial, or *tropical* year. If the equinoctial points remained fixed, this period would coincide with a complete revolution of the sun in the ecliptic, or—which is the same thing—of the earth in its orbit. But, owing to a cause which it belongs to physical astronomy to explain, the equinoctial points have a slow backward motion on the ecliptic of 50″ annually; when the sun, therefore, leaving the equinoctial point Aries one spring, arrives at that point next spring, he has yet 50″ to travel before he has completed a circuit among the stars, which makes a *sidereal year*. The return of the sun to the same equinoctial point thus *precedes* its return to the same point in the ecliptic; and this fact is known as the *precession of the equinoxes*. The length of the equinoctial or tropical year is 365 days, 5 hours, 48 minutes, 50·4 seconds; of the sidereal year, 365 days, 6 hours, 9 minutes, 10·4 seconds.

The equinoxes thus retrograde 1° in 71·6 years; and in 25,868 years they will make a complete revolution of the ecliptic. Celestial longitudes being counted from the point Aries, are slowly increasing: since the first catalogues were formed, the longitudes of the fixed stars are all greater by 30°.

The Calendar.—How the civil year, which must contain an exact number of *whole* days, is adjusted to the natural year, which contains fractions of a day, is explained in CHRONOLOGY.

Aberration of Light.—One direct proof of the earth's motion in its orbit is found in a phenomenon discovered by the illustrious astronomer Bradley. Vision, it is well known, arises from rays of light proceeding from any object, and entering the eye; and we see the object in the direction in which the rays have come. If both the body giving forth light, and that one which receives it, be at rest, the former will be seen in its true place, at least in so far as aberration is concerned; but let either of the bodies move, and this will not be the case. In order to render this plain: suppose a shower of hail to fall perpendicularly upon a number of tubes—say the pipes of an organ; if the organ remain stationary, the hailstones will descend sheer from the top to the bottom, without any deviation right or left; but move the organ in any direction, and they will strike the side opposite to the direction in which the motion is made. To make them descend to the bottom of the tubes in motion without striking, the tubes must be slightly inclined forward in the direction of the motion. This represents exactly the circumstances under which light from a heavenly body enters the eye or the tube of a telescope. The earth, bearing the spectator with his telescope, is moving at the rate of nineteen miles a second; light moves with the amazing velocity of 192,000 miles per second, vastly faster than hailstones, still requiring sensible time; and in order to adjust the telescope to these two motions, it must be directed, not exactly to the point from which the light proceeds, but slightly in advance of it. The object thus appears displaced, and the amount of displacement is *aberration*.

THE MOON.

Next to the sun, the moon is to us the most striking of all the heavenly bodies. Its disk is almost equal to that of the sun, the mean apparent diameter being 31′ 7″. The real diameter is 2153 miles, which makes its volume about the forty-ninth part of that of the earth. Its mass or weight, however, is only about the ninetieth part of the earth's mass; so that its density is not much above half that of the earth, or not quite three times the density of water.

The moon's orbit being elliptical, and the earth in one of the foci, its distance varies to the extent of 30,000 miles; and this causes a corresponding variation in its apparent diameter. The moon's disk is thus sometimes larger than that of the sun, so as to cause a total eclipse of the latter, when it passes over it. The moon's path in the heavens does not coincide with the sun's path or ecliptic, but crosses it at two opposite points, at an angle of 5° 9′. These two points are called the *moon's nodes*—that by which the moon passes from the south to the north side of the ecliptic being the *ascending* node, the other the *descending* node. These points change their position, so as to make a complete revolution of the ecliptic, in a retrograde direction, in 18·6 years. When the moon is nearest to the earth, it is in *perigee;* and when at its greatest distance, it is in *apogee*. These two points are called the moon's *apsides;* they shift their position on the ecliptic as well as the nodes, but in the opposite direction, or from west to east. This motion is called the *progression of the moon's apsides;* the revolution is completed in 8·85 years.

A month.—The moon goes round the earth in her orbit in about twenty-seven days; and this motion makes her seem to us to move eastward among the stars at the rate of a little more than the length of her own apparent diameter in an hour. The time that the moon takes to make one complete revolution round the earth—that is, to return to the same place among the stars—is called a *sidereal* month or lunation. But while the moon is performing this journey, the sun has also advanced, though at a slower pace, in the same direction; and it takes the moon upwards of two days more to overtake the sun, as it were, and get again into the same situation with respect to that luminary and the earth. When it has done so, it has completed a *synodic* revolution. The synodic period or lunation, then, is the period between two new moons, or two conjunctions of the sun and moon; it is the lunar month, and its mean length is 29 days, 12 hours, 44 minutes. The sidereal month is 27 days, 7 hours, 43 minutes.

The moon, besides revolving round the earth, also turns on its own axis, and, by a remarkable coincidence, the rotation on the axis is completed in exactly the same time as the revolution in the orbit; which is probably the case with all other secondary planets. In consequence of this coincidence, the same side of the moon is always turned towards the earth, as is evident from her surface presenting constantly the same easily recognised marks in the same positions.

Owing to the rotation of the moon on her axis being quite uniform, while her motion in her orbit is not so, a little more of her eastern or of her western edge is seen at one time than at another; and from the axis not being quite perpendicular to the plane of the orbit, the north and south poles of the moon lean alternately a little towards the earth, and give us an occasional peep further of the northern and southern regions. These phenomena are known by the name of the *moon's librations*—the one set being *librations in longitude*, the other, *in latitude*.

As the moon, turning on its axis once in a little more than twenty-seven days, presents every part of its surface in succession to the sun in that time, the *day* of the moon is consequently nearly a fortnight long, and its *night* of the same duration.

Phases of the Moon.—The light of the sun, falling upon the moon, is partly absorbed into its body; but a small portion is reflected or thrown back, and becomes what we call *moonlight*. The illuminated part, from which we derive moonlight, is at all times increasing or diminishing to our eyes, as the moon proceeds in her revolution round our globe. When the satellite is on the opposite side of the earth from the sun, or in *opposition*, we, being nearly between the two, see the whole of the illuminated surface, which we accordingly term *full-moon*. As the moon advances in her course, the luminous side is gradually averted from us, and the moon is

said to wane. At length, when the satellite has got between the earth and the sun, or into *conjunction*, the

Phases of the Moon.

luminous side is entirely lost sight of; the moon is then said to *change*. Proceeding in her revolution, she soon turns a bright edge towards us, which we call the *new-moon*. This gradually increases in breadth, till she is one quarter of her circuit from the sun, or in *quadrature*, when half the disk is illuminated, and it is then said to be *half-moon*. The luminary, when on the increase from *new* to *half*, is termed *crescent* (increasing); when between half and full, it is *gibbous* (hump-backed).

In the early days of the new-moon, we usually see the dark part of the body faintly illuminated, an appearance termed the *old-moon in the new-moon's arms*. This faint illumination is produced by the reflection of the sun's light from the earth, or what the inhabitants of the moon, if there were any, might call *earth-light*. The earth, which occupies one invariable place in the sky of the moon, with a surface thirteen times larger than the apparent size of the moon in our eyes, is then *at the full*, shining with great lustre on the sunless side of its satellite, and receiving back a small portion of its own reflected light—the 'reflection of a reflection.'

The moon's rays were till recently believed to be without heat; but by concentrating them in a lens of three feet diameter, the Italian philosopher Melloni obtained a sensible elevation of temperature.

The *physical condition of the moon* is in many respects remarkable. It is ascertained to be without any atmosphere, nor is there the least trace of liquid of any kind. The direct rays of the sun will thus shine for fourteen days with a fierceness far beyond anything experienced on the earth; but there can be no accumulation of heat, and on the unilluminated side the cold must be for other fourteen days more rigorous than on the summits of our loftiest mountains.

The aspect of the surface, seen through a powerful telescope, is singularly rugged and desolate. The whole

N.

S.

Telescopic appearance of the Moon.

visible hemisphere is thickly covered with mountain masses, and these mountains form the brightest parts of the surface. The parts that have a more uniform gray tint were formerly supposed to be water, and received such names as the Sea of Cold, the Sea of Showers, the Sea of Nectar. They are now seen to be regions of land diversified with permanent inequalities, only of less magnitude than the more mountainous parts.

'The mountains of the moon are not mountains, in the common acceptation of the term; they are circular pits, hollowed out into the lunar substance, and surrounded by a ring-shaped elevated border, more or less abrupt and broken. The floor of the pit is in every case depressed far below the general surface of the moon; the ring-shaped ridges are therefore much more precipitous on the inner than on the outer side. Very frequently, one or more isolated peaks arise from the centres of these depressed floors. The lunar surface is completely studded with circular and rimmed depressions of this nature. Those of small size are too numerous to be counted. There are some that are not more than 300 or 400 yards across; others exceed 100 miles.'

These circular mountains are denominated, according to their magnitudes, *Bulwark Plains*, *Ring-mountains*, *Craters*, and *Holes*. The most remarkable of the ring-mountains is that called Tycho, after the illustrious Danish astronomer. It is situated towards the southern border of the disk, a little to the left, and may be recognised on the figure by radiant streaks proceeding from it like rays. The enclosure is a circle forty-seven miles in diameter, and the inner side of the ridge is as steep as a wall, and 16,000 feet high, while the height above the surrounding surface outside is only 12,000 feet. On the floor of the enclosed hollow stand a few isolated hills, one of them nearly a mile in height.

The heights of the solar mountains are measured by means of the shadows they cast during the phases. More than a thousand have been thus determined, several of which reach a height of 23,000 feet. Considering that the moon's diameter is little more than one-fourth that of the earth, the solar mountains are thus on a much grander scale than the terrestrial. The mountains of the moon have in many respects a volcanic character; but no trace of an *active* volcano has yet been discovered; and the vast dimensions of most of them, together with other circumstances, make it difficult, with respect to many of them at least, to conceive them as formed by volcanic agency.

The Moon and the Weather.—It is an almost universal belief that the changes of the moon influence the weather; but when put to the test of accurate observation, this opinion is found to be completely groundless: there is, in fact, no correspondence whatever between the changes of the moon and those of the weather.

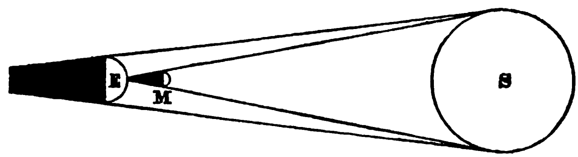
Innumerable other influences have been attributed to our satellite, extending over all nature; the growth of plants, the health or disease of animals and men, and the soundness of the mind, have all been supposed subject to her sway. Many of those fancies are dying out of themselves; they have as little foundation in fact as the peculiar 'moist' character which, in the days of astrology, was ascribed to the moon. The term *lunacy* is a relic of times when the human body was looked upon as a microcosm, in which the heart represented the sun, the brain, the moon, and every planet ruled its special organ. Yet the connection between the phases of the moon and paroxysms of insanity and other nervous disorders, seems supported by such an amount of testimony, that it still finds advocates, and even men of science like Arago recommend caution in deciding against it.

ECLIPSES.

Eclipses are caused by the positions of the earth and moon with respect to each other and to the sun. An eclipse of the sun takes place when the moon is between the sun and earth; and an eclipse of the moon is the result of the earth being between the sun and moon. In

other terms, the shadow of the earth cast upon the moon causes a lunar eclipse, and that of the moon upon the earth causes a solar eclipse.

The accompanying figure represents two positions of the moon: in the one she is in the earth's shadow, and totally eclipsed; in the other, her shadow is falling upon



a part of the earth's surface, and eclipsing the sun to that part. Within the limited circle on which the moon's shadow, or *umbra*, falls, no part of the sun is seen, or he is in *total* eclipse; within a larger space round that spot, the moon seems to cover only part of the sun's disk, making a *partial* eclipse; and this space is within the *penumora*, as it is called. When the moon happens to be so far distant from the earth that the cone of the shadow falls short of the earth, then a spectator standing immediately under the apex, or point, sees the moon covering the middle part of the sun's disk, and leaving a ring of it visible. This is an *annular* eclipse.

If the moon's orbit were in the same plane with that of the earth, there would be an eclipse of the sun at every conjunction, and one of the moon at every opposition; but as the two circles cross one another, it is only when the moon is in or near one of her nodes at the time of conjunction with the sun, that she can come nearly into a straight line with the earth and sun, so as to cover any part of the latter's disk, or that she can come into the earth's shadow at opposition. If a conjunction or new-moon happen while the moon is within about 16° of a node, the moon's disk will overlap, more or less, that of the sun. Now, the motions of the two orbs bring them within those limits at least twice every year, so that there *must* be annually *two* solar eclipses, and there *may* be *four*. The limits for a lunar eclipse are shorter, and a whole year *may* elapse without one occurring. There are thus more solar eclipses than lunar, though the general impression is to the contrary. This arises from the circumstance that, whenever an eclipse of the moon occurs, it is seen at all places where the moon is above the horizon, and the atmosphere unclouded; whereas an eclipse of the sun is confined to a limited tract.

These eclipses, like all other things about the heavens, can be predicted with almost perfect accuracy. It is also possible to calculate backwards, so as to find the probable date of remarkable eclipses recorded to have happened in antiquity.

Another effect that sometimes happens is the *occultation* of one body by another; as when the moon passes over a star or planet, and hides it from our view. This is quite different from an eclipse, which requires something to lie between a planet or satellite and the *sun*. The great breadth of the moon enables it to pass over a considerable number of stars every month.

The inferior planets, Mercury and Venus, sometimes cross the sun's face, on which occasion they may be traced by a telescope as a dark speck moving from one edge over to another, and then disappearing. These are *transits*, and are of importance in ascertaining the sun's parallax and distance.

In times when people's fates and fortunes were predicted from the positions of the planets at the hour of their birth, much stress was put upon *conjunctions* and *oppositions*. When two bodies are in the same quarter of the heavens, so as to be near one another, or have the same *longitude*, they are said to be in *conjunction;* when they are half a circle apart in longitude, they are in *opposition*. Astronomers use the sign ☌ to indicate conjunction; and ☍ to indicate opposition.

COMETS.

'Comets,' says Humboldt, 'at the same time possess the smallest mass, and occupy the largest space of any bodies in the solar regions; in their number, also, they exceed all other planetary bodies, except, perhaps, aërolites, amounting to many thousands at least.' Comets have usually two parts—a body or head, and a tail. The head has the appearance of a round nebulous mass of light, with usually a brighter part in the centre called the nucleus, but so far from containing anything solid, that the smallest stars are seen through the densest part of the substance. The tail is a still lighter luminous vapour, surrounding the body, and streaming far from it in a direction generally opposite to that in which the sun is situated, as if repelled by that luminary, and often curved. A vacant space has been observed between the body and the enveloping matter of the tail, which also appears sometimes less bright along the middle, immediately behind the head, as if it were a stream which the head had parted in two.

Whether comets are self-luminous, or derive their light from the sun, is a doubtful point. The tail is by no means essential to a comet; by far the greater number have no such appendage, appearing merely as a nebulous disk. In some cases, the tail has been seen gradually to form as the comet approached the sun, and to go through a number of striking transformations. Several distinct tails have at times been observed.

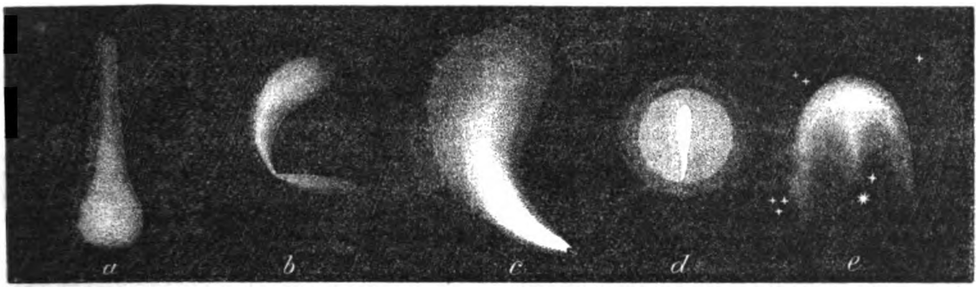
With regard to the motions of the comets, instead of revolving, like the planets, nearly in the plane of the sun's equator, it is found that they approach his body from all parts of surrounding space. At first, they are seen slowly advancing, with a comparatively faint appearance. As they approach the sun, the motion becomes quicker, and at length they pass round him with very great rapidity, and at a comparatively small distance from his body. The comet of 1843 approached within one-seventh of his radius. When near the sun, their brilliancy is greatly increased, but their volume is contracted. As they recede, their motion becomes gradually slower, and their brilliancy diminishes, and at length they are lost in distance.

In moving round the sun, comets obey the same general laws that regulate the planets. They do not, however, all describe ellipses; for Newton has shewn that a body moving round another by the force of gravitation, may move in any of the curves called *conic sections;* that is, in an ellipse, a parabola, or a hyperbola. Of the 200 cometary orbits that have been ascertained, about forty are known with greater or less certainty to be ellipses; while the others passed through our system in hyperbolas or parabolas—mostly the latter—open curves, which never return into themselves, but go on widening to infinity. Now, the comets that move in shut orbits, or ellipses, must return to the sun again and again, and may therefore be considered as members of the solar system. The others are only casual visitors; they can never return, but must run off into the immensity of space.

The most remarkable of the comets ascertained to return is one usually denominated Halley's Comet, from the astronomer who first calculated its period. It revolves round the sun in about seventy-five years, its

last appearance being at the close of 1835. The annexed cut represents some of the various appearances it presented on that occasion in different parts of its orbit—*a*, *b*, *c*, in approaching the sun; *d*, *e*, in retreating.

Another, called Encke's Comet, from Professor Encke



of Berlin, has been found to revolve once in 1207 days, or 3⅓ years; but in this case the revolving body is found, at each successive approach to the sun, to be a little earlier than on the previous occasion; as if, from some retarding cause, its orbit were gradually lessening, and as if the comet might consequently in time fall into the sun. The cause of this obstruction is supposed by some to be the ether whose vibrations are held to constitute light. A third, named Biela's Comet, revolves round the sun in 6½ years. It is very small, and has no tail. In 1832, this comet passed through the earth's path about a month before the arrival of our planet at the same point. If the earth had been a month earlier at that point, or the comet a month later in crossing it, the two bodies would have been brought together; what the consequences might have been, we know too little of the constitution of comets to judge. During its visit in 1846, this comet was seen to separate into two distinct comets, which kept moving side by side, till they disappeared. On the return of the comet in the autumn of 1852, the distance between the two nuclei had much increased, and their divorcement is now considered complete. Four comets, besides that of Halley, have periods a little over seventy years; to others have been assigned periods of many thousands of years, liable, however, to much uncertainty. Comets are often affected in their motions by the attraction of the planets; Jupiter, in particular, is said to be a perpetual stumbling-block in their way. In 1770, a comet got entangled amidst the satellites of that planet, and was thereby thrown out of its usual course, while the motions of the satellites were not in the least affected by its proximity. This proves the extreme lightness of the matter composing comets.

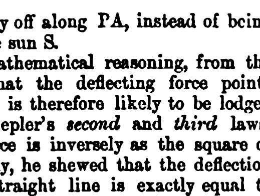
The comet now called Halley's, at its appearance in 1456, covered a sixth part of the visible extent of the heavens, and was likened to a Turkish scimitar. That of 1680, which was observed by Sir Isaac Newton, had a tail calculated to be 60,000,000 miles in length—a space two-thirds of the distance of the earth from the sun. There was a comet in 1744 which had six tails, spread out like a fan across a large space in the heavens.

MECHANICAL OR PHYSICAL ASTRONOMY.

Not long after Kepler had made those remarkable discoveries which completed the view of the regular courses and periods of the celestial motions; the *causes* of the motions, or the powers and forces whereby they are sustained, were also discovered by Sir Isaac Newton. He was the first to shew that the vast planetary balls whirl about their own centres, and fly through the celestial spaces, on exactly the same principles as a cannon-ball or a stone moves when thrown into the air. The principles of celestial mechanics, therefore, are the principles of motion discovered from the observation of bodies on the earth; they are the three Laws of Motion and the doctrines of the Composition of Forces, as illustrated under MATTER AND MOTION, and the doctrine of Universal Gravitation.

The fall of unsupported bodies to the earth is the most familiar action in nature; but it is not two centuries since Newton discovered that this action extends to the moon, the sun, and the planets. He proved that the moon is constantly falling towards the earth, and would fall into it, but for another motion she has, which is always carrying her off, and would of itself shoot her far away into space in a straight course; so that her actual circuit is the balance of two forces—one her weight, or gravity, towards the earth (*centripetal* force), the other an undying impulse to fly off at a tangent, like a whirled stone when the sling is let go (*centrifugal* force).

It was through the application partly of the laws of motion, and partly of Kepler's laws, that Newton established the universal prevalence of gravity. It being once found that the planetary motions could be kept up by a combination of forces; that is, by a force that projected the body once for all into free space with a great velocity, which, by the first law of motion, would be always kept up, whether it went off straight through space, or were compelled to go round a circle—and some second force to hold it in that circle; the great question arose, What is the *central* force—what power is it that causes the moon to fall towards the earth, instead of running off; and in like manner obliges the planets, with their immense speed, to keep constantly falling towards the sun? A planet P, if not held in by some tie, would fly off along PA, instead of being always carried round the sun S.



Newton proved by mathematical reasoning, from the *first* law of Kepler, that the deflecting force points exactly to the sun, and is therefore likely to be lodged in his body. From Kepler's *second* and *third* laws, he proved that the force is inversely as the square of the distance; and, finally, he shewed that the deflection of the moon from a straight line is exactly equal to the fall of a stone, if it were at the distance of the moon. The moon being sixty times further off from the earth's centre than we are, gravity is there 3600 times weaker; so that the speed acquired by a stone falling one second near the earth's surface, would be acquired only by falling an hour at the height of the moon. And it can be easily proved by calculation that the falling action of the moon is, in an hour, exactly that of a stone in a second. It being thus shewn that the moon is deflected by gravity, it was then concluded that the planets are deflected to the sun by the same cause; or

that gravity is the great *central* force throughout the solar system.

Newton also shewed that gravity is a *mutual* action; or that it is not the moon falling to the earth, but the earth and moon moving towards each other. If the two were equal, they would approach at an equal rate; but the earth being the largest, its approach to the moon is by so much slower than the moon's approach to it. The consequence is, that in the revolution of the moon, the centre is, not the earth's centre, but the centre of gravity of the earth and the moon, or that point between them where they would be equally balanced on a lever; so the sun, being attracted by all the planets, is not at rest, but is drawn about hither and thither; his enormous size preventing him from being moved very far. The centre of gravity of the solar system is not in the sun's centre, but between his centre and surface.

After thus identifying the mechanical causes of the planetary motions, Newton deduced all the laws of Kepler from the combination of the two great forces of Gravitation and Straight Impulse. In this way he found that these laws are not strictly true, as given by Kepler, and that therefore the prediction of the places from them could not be perfectly accurate. Not only was the sun's centre not the true focus of the ellipse, but he shewed that not one of the paths is an exact ellipse or a perfect oval. If there were only one planet to the sun, that planet would describe a perfect ellipse; for it can be proved that if a body is projected in free space, under the action of the sun's gravity, it must move round the sun, either in a circle, an ellipse, or in one of the other figures of the conic sections (the parabola and hyperbola); and Kepler's laws will be strictly true, taking the centre of gravity as the centre of the motion. But if a second planet is introduced, this planet is not only attracted by the sun (and the sun attracted by it), but there is an attraction between it and the first planet which disturbs the motion of both; neither of them can in this case move in an exact ellipse. The more planets there are, the greater the mutual action, and the more they are liable to be disturbed in their elliptic courses.

In like manner, if the moon and the earth were alone in the universe, the moon would go round the common centre of gravity of the two in a perfect ellipse; but as both move round the sun, and he acts upon both, very great deviations take place from the elliptic orbit; in fact, the application of Kepler's two first laws to the moon could never predict her place with anything like accuracy. The case is still worse with the satellites of Jupiter, which disturb one another, besides suffering disturbance from the attraction of the sun.

Perturbations.—But the same discoveries that shew the defects of Kepler's laws, give the means of correcting those defects, or of calculating the disturbing influences, so as to predict what the real motions will be under those disturbances. The whole series of these calculations make up the body of mechanical or physical astronomy; and the special disturbances are known as *perturbations* or *inequalities*. In calculating them, astronomers first suppose the case of one body revolving about a second, and disturbed in its regular orbit by a third; this is what is called the *problem of the three bodies;* the disturbing effect of each separate cause being thus found, the whole are then combined.

Masses of the Heavenly Bodies.—The theory of universal gravitation gives us the means of comparing the weights of the heavenly bodies, as if they were weighed on a steelyard. Thus the fall of the earth towards the sun in an hour, can be compared with the fall of the moon to the earth in an hour; and the two quantities multiplied by the squares of the two distances, will give the proportion between the mass of the sun and the mass of the earth, which is about 355,000 to 1. When we remember that the *bulk* of the sun exceeds that of the earth more than a million of times, we see that the matter of the sun is much lighter than the material of the earth. In the same way, Jupiter's mass is found to be 340 times that of the earth.

To find the actual density or specific gravity of the different bodies of the solar system, and compare it with a fixed standard, such as water, it is necessary to know the average density of the whole earth. This has been sought by comparing the attraction of some known body with the attraction of the globe. Thus, Dr Maskelyne attempted to calculate the attraction of a mountain in Perthshire, by finding how far it made a plumb-line to deviate from the perpendicular. In this experiment the plumb-ball was supposed to be attracted downwards by the general mass of the earth, and sideways by the mountain; and it could thus be seen how many times the whole earth surpassed the mountain in gravitating force. If the mountain itself then were measured, and its composition ascertained, so as to give the density of its rocky material, the entire mass of the mountain would be obtained, and from that the entire mass of the earth. The result of this experiment was, that the earth is, on an average, $5\frac{1}{2}$ times denser than water, or more than twice the density of granite or sandstone rock. Other experiments, of a different kind, have given much the same determination. From this we can estimate the densities of the sun, moon, planets, and satellites.

The Figures of the Heavenly Bodies, how caused.—It has already been seen that the sun and planets are, in general, round masses, with a slight flattening, which seems to be connected with the rapidity of their whirl. Now, both the general roundness and the flattening can be shewn to arise from ordinary mechanical laws, such as we see operating on the earth, provided we suppose that the planets were at one time soft fluid masses. If a fluid mass of attracting particles are left to themselves—that is, if there be no external compulsion, either attraction or pressure—they will always assume the *round* shape. Thus the drops of rain, and liquid drops in general, are nearly round; and they would be perfectly so if they were in free space, out of the reach of attracting bodies. On the same principle, a soft planetary mass, or a liquid satellite, would, by its own gravity, cohere into a round ball; so that the geometrical observation agrees exactly with the mechanical theory.

In the second place, the *flattening* is the consequence of the round balls being made to whirl, instead of remaining at rest. When a body is whirled, the matter at the surface acquires a tendency to fly off, so as to oppose the general attraction towards the centre. If the whirled body is soft or liquid, it cannot remain at rest, or in equilibrium, in its round form, inasmuch as the matter at the equator is rendered lighter by its centrifugal tendency, and is not a sufficient balance for the matter at the poles. To restore the balance, there must be a greater depth from the equator to the centre than from the poles to the centre; in other words, the equatorial width must exceed the polar width, which is what we actually find in all the revolving bodies. The planets also that revolve the most rapidly, as Jupiter and Saturn, are found to be the most elliptical.

That the matter on the equatorial regions of a planet gravitates less than at the poles, is proved by experiments on the earth. Bodies are found to weigh less in tropical countries than in high latitudes. The fall of a stone is less rapid, and the swing of a pendulum is slower; all shewing a diminished gravity.

Tides.—The tides are those regular movements of the sea whereby it rises and falls on its shores about twice a day. They may be regarded as a slight disturbance of the figure of the earth, caused by the attraction of the sun and moon. The methods of calculating them are similar to the investigations of the general question of the figure; hence they are regarded as a portion of the same subject. They are more particularly described under PHYSICAL GEOGRAPHY.

Precession of the Equinoxes.—It has been already

explained in what this consists—namely, in a slow retrograde motion of the equinoctial points upon the ecliptic, carrying them from east to west at the mean rate of 50″ in a year. The cause is to be found in the combined action of the sun and moon on the protuberant mass of matter accumulated at the earth's equator, which tends to alter the position of that equator with regard to the plane of the ecliptic. The exact nature of this action is too complex for description here; but combined with the rotation of the earth on its axis, the result is the regression of the equinoctial points above mentioned; while, as a necessary consequence, the celestial pole describes, at the same rate, a circle among the stars round the pole of the ecliptic at a distance equal to the obliquity of the ecliptic. Its motion, however, is not quite uniform or straight, but in a waving line, alternately approaching and receding from the pole of the ecliptic. This secondary disturbance, which is caused by the fluctuating position of the moon's nodes, is known as the *nutation* of the earth's axis.

The poles of the earth do not, then, point always to the same places among the stars. The present position of the north pole is within a degree and a half of a bright star in the constellation of the Lesser Bear. Its motion will bring it gradually nearer until it is within half a degree of that star, after which it will recede from it. Its course may be traced by drawing a circle on a celestial globe round the north pole of the ecliptic, at the distance of 23½°. The celestial pole describes this circle in 25,868 years. Twelve thousand years hence, it will be near one of the brightest stars in the heavens, called α Lyræ, which will then be the pole-star.

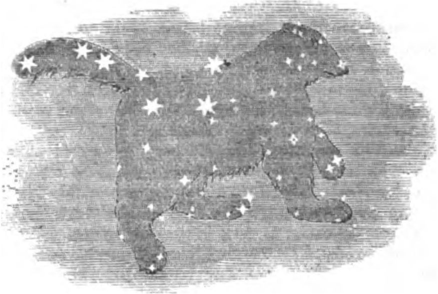
Stability of the System.—It is natural to inquire whether the numerous perturbations which all the bodies are subject to, are such as in the long-run to overthrow the present arrangements of the system. If any cause were at work to diminish steadily the mean distance of a planet, it must of course ultimately fall into the sun. It has, however, been proved that the total effect of all the mutual disturbances has no such tendency. Though there are secular variations that may go on increasing for thousands of years, they will necessarily decrease continually for periods of like duration, and the limits within which this secular oscillation is confined are in all cases extremely narrow.

The only thing that can bring about a decay in the system is a resisting medium—that is, if the planetary spaces, instead of being perfectly blank and void, are filled with a very thin gas or ether that would impede the motion of bodies, as our own atmosphere resists any body that is impelled through it. It is at present doubtful if such an ether exists; it is certain that, if it does exist, it is exceedingly rare, and cannot produce any perceptible effect in less than thousands of years; still, if it exist at all, it will tell some time or other, and will have the effect of lessening the mean distances, and contracting the orbits. The question of a medium is expected to be decided by the study of the comets.

SIDEREAL ASTRONOMY—THE FIXED STARS.

The first thing that strikes us about the stars is their difference as to brightness. They can be classified according to this feature. The most brilliant are said to be of the first *magnitude;* the next of the second; and so on. The smallest stars visible to the naked eye are of the sixth or seventh magnitude. The number of stars visible in one hemisphere may be about 2000, making in all 4000. About twenty-four are reckoned of the first magnitude. By using telescopes, a vast mass of new stars come into view, which are reckoned as far as the seventeenth magnitude; the numbers and closeness increasing with every increase of the telescope's power.

From the earliest times, the stars have been divided into groups called *constellations*, which were named from fancied resemblances to animals or other figures. Thus, a group in the northern part of the sky is called *Ursa Major*, or the Greater Bear. From the figure of the



Constellation Ursa Major.

seven more conspicuous stars, it is sometimes called *the Plough*. Another well-marked group is called after the mythical personage *Orion*. Individual stars are indicated by the letters of the Greek alphabet or by numbers, as η *Ursæ Majoris* (in the tip of the tail of the Greater Bear), 24 *Comæ*. Some remarkable stars have names, as Aldebaran (α *Tauri*), Sirius (in the nose of Canis Major). By means of a celestial globe, or a set of star-maps, the more conspicuous constellations may be soon recognised.

The stars are believed to be so many suns, shining by their own light, and each being perhaps the centre of a system of planets, the abodes of sensitive and intelligent existence. Their immense distance reduces them all equally to mere points of light; in the most powerful telescopes they shew no *disk*, and differ from one another, not in *magnitude*, properly speaking, but in brilliancy.

When the same methods of measurement that determine the distances of the sun and planets, were applied to the fixed stars, they seemed for a long time to fail. Two observations of any star made from different points of the earth's orbit, though at the enormous distance of 200,000,000 miles apart, gave no appreciable displacement or parallax. As a parallax of one second ($\frac{1}{3600}$) of a degree would imply a distance equal to 200,000 times that of the sun, and as it was certain that a parallax of that amount could be measured if it existed, it was inferred that no star was at least within that distance. More refined modes of observation have recently detected the parallax of several stars, and determined positively their distances. In stating these distances, it is convenient to take as a standard or unit the distance due to a parallax of one second—namely, 200,000 distances of the earth from the sun, or twenty millions of millions of miles, a space which it takes light 3¼ years to traverse, though it travels 192,000 miles per second. The nearest yet measured is a fine double star in the southern hemisphere (α Centauri), calculated to be a little greater than one such sidereal unit; Sirius, the brightest of the fixed stars, is at a distance of about four units, or eighty millions of millions of miles, requiring upwards of twelve years for the transmission of its light.

Temporary and Periodical Stars.—It is ascertained, beyond doubt, that some stars, at one time visible, and registered by ancient astronomers, are not now to be seen; while many instances are on record of stars which have come into sight for a time, and then gradually vanished. Besides these temporary stars, there are others that undergo periodical increase and diminution of lustre, and are called *periodical stars*. The star Omicron, in Cetus, for instance, goes through a series of variations in a period of about 330 days. It is seen as bright as a star of the second magnitude for about a fortnight; then gradually diminishes for three months, till it becomes invisible, in which state it remains for five months, when it again becomes visible, and gradually increases till it regains its former brightness, more or less—for it does not always reach the same

degree of lustre. There are eleven other stars which exhibit analogous phenomena, some of them at intervals of 500 years.

Binary and Multiple Stars.—Another variety in the nature of these luminaries is their being in some instances not *single* stars, as they appear to the naked eye, but a group of two or more, evidently, from their motions, forming one system. The star Castor, one of the Twins, is found, when much magnified, to consist of two stars, of between the third and fourth magnitude, within five seconds of each other. Upwards of 6000 such groups have been observed. Many of the double stars, no doubt, are thus accidentally brought together, the one being at a great distance behind the other; but of a great number, it has been fully ascertained that they are each a system, with a reciprocal relation to each other. They are therefore called *binary stars*, or more properly, *multiple* stars. It is generally observed that they move round each other within a certain time, and in elliptical orbits; the revolution of Castor, for instance, is supposed to be accomplished in 252 years.

Proper Motion of Stars.—When we speak of the stars being *fixed*, it is only as compared with the planets. There is no such thing as absolute fixity in the universe. Besides the revolutions of the double stars, a great many stars have been observed to be slowly but constantly carried away from their places in the heavens. This *proper motion*, as it is called, has in one instance shifted the situation of a star in the heavens, in the course of fifty years, over $\frac{1}{17}$th of a degree. Founding upon these displacements of the stars, it has been concluded that our sun, accompanied by his attendant planets, is in motion towards a region of space in the direction of the constellation Hercules. The velocity assigned to this movement is 422,000 miles a day. Some astronomers have even sought to assign a centre of gravity about which our whole star-system is in rotation.

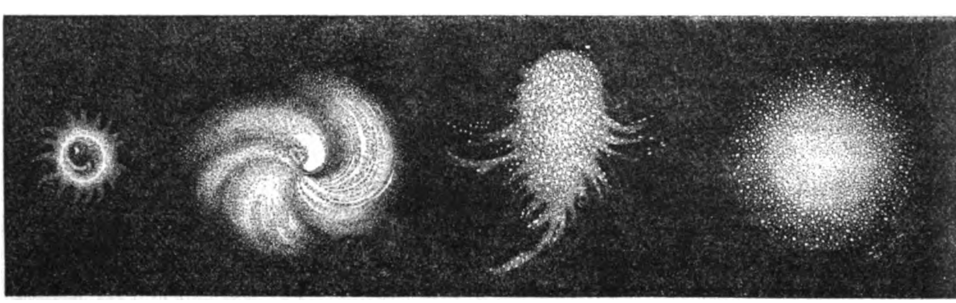
Milky-way.—The stars are very unequally scattered over the sky. We may always observe a whitish band arching the heavens, called the *Milky-way*, which appears to the eye, and still more to the telescope, as a dense mass of starry dust. Sir William Herschel, by gauging, as it were, the depth of the starry stratum in all directions, came to the conclusion, that the stars forming our firmament do not extend indefinitely into space, but are limited in all directions, the mass having a definite shape. He conceived the stratum to be thin in proportion to the length and breadth, and that looking through the mass of stars forming the depth in these directions, gives the appearance of the Milky-way. As the Milky-way divides into two branches, there must be a bifurcation of the stratum. Our place in the system is conceived to be not in the centre, but nearer to one end and to one surface.

Remote Star-systems, Nebulæ.—From the grand idea of the solar system, we thus rise to the vastly grander idea of a *stellar* system, composed of countless myriads of solar systems, many of them, perhaps, surpassing our own in magnitude, and held together by the universal bond of gravitation. But this star-system, which we may call our own, inconceivably vast as it is, is but an item of the heavenly inventory. Far beyond its bounds, the modern telescope has descried similar systems in great numbers, each hanging in some tolerably defined shape in the depths of space, and generally capable of being resolved, if not exactly into stars, into what has been expressively called *star-dust.*

A few of these remote systems are visible to the naked eye, as faint luminous spots in the heavens; but by means of powerful telescopes, more than 4000 have been observed and catalogued. They are generally spoken of collectively as *nebulæ*, from their cloud-like appearance. Many of them are resolvable into individual stars, even with a moderate telescope, but others were found to resist even the powerful telescope of Sir William Herschel; and he accordingly made a distinction between clusters of stars, or resolvable nebulæ, and nebulæ properly so called, which presented no appearance of stars. These last were conceived to be elementary sidereal matter in a diffused and gaseous form—matter in the course of being condensed to stars and systems—belated portions, so to speak, of the same soft and diffused material which, countless ages ago, was condensed into the defined bodies forming the remainder of our star-system! But in 1846, the powerful telescope of Lord Rosse shewed that one of the most marked of these nebulæ (that in Orion) did really consist of an immense irregular mass of stars, previously undiscernible, from being situated so remotely in the depth of the starry spaces. It has consequently been pronounced as extremely doubtful if there are any masses of diffused or, properly speaking, nebulous matter in the regions of space.

These star-systems are of various forms, but in general, as has been said, tolerably well-defined. Several exhibit to Lord Rosse's telescope most remarkable and even startling shapes. In the *Magellanic clouds*, a nebulous object in the southern hemisphere, there is one remote star-system, compared by Sir John Herschel to '*a bunch of ribbons disposed in what is called a true-lover's-knot!*'

The resolution of nebulæ into stars, however it may



Nebulæ and Clusters.

affect theories, infinitely exalts our conceptions of the magnitude and extent of the material universe. 'Look,' says Professor Nichol, 'at a cloudy speck in Orion, visible, without aid, to the well-trained eye; *that* is a stellar universe of majesty altogether transcendent, lying at the verge of what is known. Well, if any of these lights from afar, on which the six-feet mirror is now casting its longing eye, resemble in character that spot, the systems from which they come are situated so deep in space, that no ray from them could reach our earth until after travelling through the intervening abysses during centuries whose number stuns the imagination. There must be some regarding which that faint illumination informs us, not of their present existence, but only that assuredly they were, and sent forth into the Infinite the rays at present reaching us, at an epoch further back into the past than this momentary lifetime of man, by at least *thirty millions of years!*'

GEOLOGY.

GEOLOGY (from the Greek *gé*, the earth, and *logos*, discourse) is that science which treats of the materials composing the earth's crust, their mode of arrangement, and the causes which have produced that arrangement. By the earth's *crust* is meant that external shell or covering of solid matter which is accessible to man's investigation; the term being used in contradistinction to the interior mass, respecting the nature and composition of which we can know nothing by inspection. Though this crust is of no great thickness, it presents a great multitude and variety of matters for inspection, and reveals to us inductively an ancient history of the most interesting kind. We trace in it a long series of physical events, many remarkable changes of the surface, and a progressive march of animal and vegetable life throughout a long succession of ages prior to the existence of man. The science must therefore be regarded as one of high dignity and importance, even as a mere department of the knowledge possessed by our species. It has also, however, a still more interesting aspect, in the guidance which it gives us regarding many useful mineral substances.

The inorganic materials of the earth's crust are presented to us in three leading varieties of form and character—first, rocks of a crystalline texture, generally seen in irregular masses, and believed to have been formed by fire—second, rocks of argillaceous, arenaceous, calcareous, or other material, always seen in beds or strata, and manifestly produced as a sediment from water—third, metallic ores irregularly scattered throughout the above rocks. For the present, we shall lay aside the last, as falling properly under the science of Mineralogy, and devote our attention exclusively to the rocks and the organic remains contained in them.

CAUSES MODIFYING THE EARTH'S CRUST.

Taking appearances presented by rocks, in connection with operations which we see going on upon the earth's surface at the present day, we become aware that the inorganic materials of the earth's crust have been subjected, throughout the long succession of ages just spoken of, to determinate natural laws effecting in them a great variety of modifications. Two great agents, which have at all times impressed themselves strongly on the senses of mankind—Fire and Water—are seen to have wrought vast results; besides a third, of whose force we are less apt to be aware—the Atmosphere. Through these causes, new masses have been brought from below to the surface, others have been worn down so as to constitute new rocks, the *low* of one period has been made the *high* of another, and *vice versâ:* to these operations, mixed throughout with the results of animal and vegetable life, the whole phenomena of geology are attributable.

The causes in question have been classified by geologists as *Degrading* and *Elevating*. These they consider as antagonistic to each other; the one as a constant agent of destruction, the other as an equally constant repairing or reproducing power, and the effect being a kind of equilibrium between sea and land.

Degrading Causes.—The degradation, wearing down, or (so to speak) destruction of the sub-aërial parts of the earth's crust, is brought about by the chemical and mechanical forces of air and water. In the first place, the disintegration or separation of particles may be effected chemically by the absorption of oxygen and carbonic acid from the atmosphere into the rock-surface which is exposed to it. This is a process continually going on. We have its effects conspicuously displayed on the surface of a hill of trap-rock, where we see first a light brown powdery soil, then a splintery bed of several inches thickness, and below that the solid rock, the process of disintegration in that rock being first into splinters, and afterwards into powder. Even granite, which is regarded as an extremely hard rock, is sometimes found pulverised in this way to the depth of several feet.

Again, water percolates through minute fissures in rocks. When frost arrives, the water freezes and swells, and thereby dislodges parts of the rock, which are precipitated into lower levels. Or it may meet some clayey veins or strata, hitherto sufficient to keep various masses together: these veins or strata, being gradually softened by the water, lose their power of cementing the masses; and the upper then fall away or slide into a lower level. A *slide* of rock from the Rossberg, in Switzerland, in 1806, filled the bottom of the vale below, destroying many villages, and causing the loss of 800 lives. The impulse of wind and rain on the surface of rock is also of great efficacy in pulverising and wearing it down, sharp points being rounded, and soft parts hollowed. In Sweden there are some large detached masses of granite, containing perforations produced by this cause, some so very large as to admit of a horse and cart passing through them. These effects may be considered as chiefly *mechanical.*

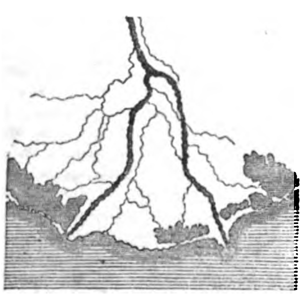
When water collects into channels, and follows its well-known tendency to find the lowest level to which it has access, it becomes a mechanical instrument of still greater force for wearing down the land. In its smallest rills, as it descends the mountain side, it cuts into the soil, and carries off whatever particles it can disengage. When gathered into brooks, its operations are still more powerful. When one of these is placed amongst mountains, every heavy shower swells it into an impetuous river, by which large quantities of detached rock and soil are brought down. In the upper parts of the courses of almost all rivers, the greater speed of descent makes up for the smaller volume of water, as far as the power of bringing down stones and soil is concerned. Again, in the lower part of the course, the smaller speed is sometimes compensated by the unevenness of the course; in which case the water is incessantly driven from one projection of the banks against another; and by that means wears away a great quantity of solid matter. The mere flowing of pure water would exert little influence on hard rocks; but all rivers carry down sand and gravel according to their velocity;* and these, by rubbing and striking against the sides and bottoms of the channel, assist in scooping out gullies and ravines, which everywhere present themselves. The Nerbudda, a river of India, has scooped out a channel in basaltic rock 100 feet deep. The river Moselle has worn a channel in solid rock to the depth of 600 feet. Sedgwick and Murchison give an account of gorges scooped out in beds of the rock called conglomerate, in the valleys of the Eastern Alps, 600 or

* It has been calculated that water running with a force of three inches per second will tear up fine clay, six inches will lift fine sand, eight inches sand as coarse as linseed, and twelve inches fine gravel; while it requires a velocity of twenty-four inches per second to roll along rounded pebbles an inch in diameter, and thirty-six inches per second to sweep forward angular stones of the size of a hen's egg.

700 feet deep. A stream of lava, which was vomited from Etna in 1603, happened to flow across the channel of the river Simeto. Since that time, the stream has cut a passage through the compact rock to the depth of between forty and fifty feet, and to the breadth of between fifty and several hundred feet. The cataract of Niagara, in North America, has receded, according to most authorities, nearly fifty yards during the last sixty years. Below the Falls, the river flows in a channel upwards of 150 feet deep, and 160 yards wide, for a distance of seven miles; and this channel has manifestly been produced by the action of the river.

Sometimes, during floods, rivers produce great changes in very short periods. A flood caused by the bursting of the barrier of a lake in the valley of Bagnes, Switzerland, moved at first with the tremendous velocity of thirty-three feet per second. From the barrier burst by the waters to Lake Geneva, there is a fall of 4187 Paris feet; the distance is forty-five miles; and the water flowed over all this space in five hours and a half. It carried along houses, bridges, and trees; and masses of rock equal in size to houses were transported a quarter of a mile down the valley.

The matter carried down by rivers is often deposited at their sides, when it constitutes what is called *alluvial land;* sometimes it is deposited at the bottom of lakes, when it forms what are termed *lacustrine deposits.* In many instances it has been deposited in large quantities at the mouths of rivers, giving rise to alluvial flats, which, from their resemblance in shape to the Greek letter Δ, have been denominated *deltas.* The triangular form of a delta, like that of the Nile (see fig.), for example, is produced by the river at a certain point inland dividing itself into two main streams, which gradually diverge till they reach the ocean, enclosing the space which constitutes the delta. As an instance of the vast extent of new land formed at the mouths of rivers, the delta of the Ganges is 220 miles in one direction by 200 in another.



Delta of the Nile.

The matter carried down by rivers, and thus deposited, is small in amount compared to that transported to the ocean. The quantity of sand and mud brought down by the Ganges to the Bay of Bengal, is in the flood-season so great that the sea is discoloured with it sixty miles from the river's mouth. Sir C. Lyell estimates the quantity of solid matter brought down by this river every day as equal in bulk to the greatest of the Egyptian pyramids. According to General Sabine, the muddy waters of the Amazon River may be distinguished 300 miles from its embouchure.

The constant action of the sea upon the land is strikingly apparent to the inhabitants of coasts. Whole islands have been destroyed by the action of tides, waves, and oceanic currents, while the remains of others rise above the surface of the water like the ruins of some desolated city. Many instances of the encroachment of the sea upon the land have been recorded. An inn on the coast of Norfolk, built in 1805, then seventy yards from the sea, was in 1829 separated from the coast by only a small garden. A church on the coast of Kent, which, in the reign of Henry VIII., was a mile inland, is now only about sixty yards from the water's edge. The island of Nordstrand, on the coast of Schleswig, was, in the thirteenth century, fifty miles long and thirty-five broad. About the end of the sixteenth century, it was reduced to an area of only twenty square miles. The inhabitants erected lofty dikes for the purpose of saving their territories; but in the year 1634, a storm devastated the whole island, by which 1340 human beings and 50,000 head of cattle perished. A little to the north of the present island stands Nordstrand-moor, which, before being separated by the sea, was a portion of the island of Nordstrand.

The matters thus worn off the elevated parts of the earth's surface, and deposited in the sea, sink and are spread out at the bottom in beds or *strata,* which subsequently become hardened into rocks, as is believed, by heat and pressure. It is a process continually going on, and which would in time carry all dry land into the ocean, and reduce our planet to a plain spherical mass, were there not a counteraction in certain forces tending as constantly, though more intermittingly to the elevation of the masses so formed in the bed of the ocean.

Elevating Causes.—As degrading forces are chiefly owing to water, so those of an elevating character are chiefly owing to fire; they are therefore sometimes comprehended under the term *Igneous Agency.*

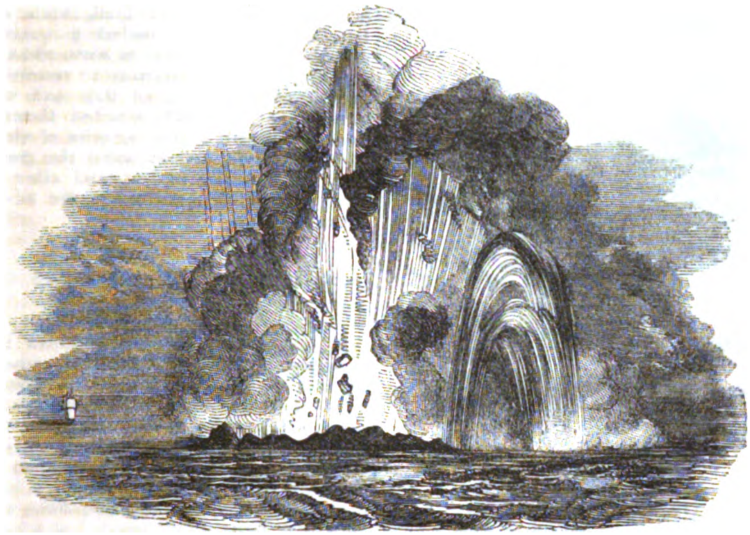
The manifestations of igneous agency at present observable may be considered under three heads—namely, *volcanoes, earthquakes,* and *gradually elevating forces.* These phenomena may be viewed as the effects of subterranean heat, operating under different circumstances. A volcano may be described as an opening in the earth's surface, bearing the general appearance of a vent of subterranean fire, and through which smoke, cinders, and ashes are almost continually issuing, but which sometimes discharges great fragments of rock, and vast quantities of melted rocky matter or *lava.* The general effect is a throwing up of earthy material, in a conical form, from a low to a high level, of which Mount Etna is one of the most characteristic examples.

Geographers at present reckon about 200 volcanic vents in activity throughout the earth. The greater number of the whole are in a line along the west coast of South and North America. There are many in the islands of the Pacific and Indian Oceans, and in the central regions of Asia. In Europe there are only three in activity—Etna in Sicily, Vesuvius in Italy, and Hecla in Iceland. But a vast number of hills throughout France, Britain, and other countries, bear the appearance of having once been active volcanoes. As volcanic action often takes place in the bed of the sea (submarine volcanoes), and as there are probably many on land not yet described by geographers, the number of such vents throughout the earth must be considerably more than two hundred.

Of the power of volcanoes to throw up large quantities of solid matter, we have many examples. During an eruption of Etna, a space around the mountain, 150 miles in circumference, was covered with a layer of sand and ashes, generally about twelve feet thick. In the first century, the cities of Herculaneum and Pompeii were buried beneath such a layer of matter by Vesuvius. In 1660, the philosopher Kircher, after accurately examining Etna, and the ground adjoining its base, calculated that the whole matter thrown out by it at its various active periods would form a mass twenty times as large as the mountain itself, which is 10,870 feet high, and thirty miles in diameter at the base. From this mountain, in 1775, there issued a stream of lava a mile and a half in breadth, twelve miles long, and 200 feet thick. At an earlier period, there was a stream which covered eighty-four square miles. In 1538, a large hill, since named Monte Nuovo, was thrown up in the neighbourhood of Naples in one night; and in 1759, in a district of Mexico previously covered by plantations, a sudden outburst of volcanic action, which

lasted several months, terminated in leaving six hills, varying from 300 to 1600 feet in height, above the old plain.

Of the effect of submarine volcanoes some interesting observations have been made in recent times. In June 1811, an island was thrown up by volcanic agency near St Michael in the Azores. Columns of cinders rose 700 or 800 feet above the surface of the sea, with a noise resembling that of distant artillery. In the course of a few days the island was a mile in circumference, and



Hotham Island, Mediterranean, in 1831.

about 300 feet in height, having a crater in the centre full of hot water. Some time afterwards it disappeared. In July 1831, a similar island was thrown up, under precisely similar circumstances, in latitude 37° 11′ north, and longitude 12° 44′ east, off the coast of Sicily. It consisted of stones, mud, and cinders, and was of circular form, about a mile and a half in circumference, with a crater of hot water in the centre 400 yards in diameter. This island, named Sciacca, or Graham's Island, existed so long above the sea as to allow of many persons landing upon it. The Bay of Santorin, in the Greek Archipelago, which is about six miles long and four broad, contained, a few years ago, three volcanic isles, the first of which rose about the year 200, the second in 1650, and the third in 1709. In a part of the bay where the water is generally several hundred feet deep, a shoal has for several years been gradually rising: about 1816, there were fifteen fathoms water upon it; in 1830, there were only three or four; and later accounts reduce it to two and a half fathoms. This rising mass was ascertained to be of solid rock, about half a mile in length by one-third of a mile in breadth; the water deepening suddenly all round it.

Many islands which have long been inhabited by man bear all the appearance of having risen in like manner from the bosom of the deep. The islands of St Helena and Ascension, the Azores, the West India Islands, Iceland, and many of the islands in the Pacific, are evidently the produce of volcanic action. 'Owyhee,' says De la Beche, 'is a magnificent example of such an island: the whole mass, estimated as exposing a surface of 4000 square miles, is composed of lava, or other volcanic matter, which rises in the peaks of Mouna Roa and Mouna Kaa to the height of between 15,000 and 16,000 feet above the level of the sea.'

The causes of earthquakes have not as yet been satisfactorily explained, but they are now generally allowed to be connected with volcanic agency. They occur less frequently, and generally with less tremendous effect in Europe than in some other parts of the world—those parts where volcanic agency is most active being also the parts where earthquakes are most frequent and most dreadful. Though their effect is sometimes to cause a sinking of the ground, they may, upon the whole, be considered as among elevating causes. It is conceived that they are produced by gases confined in the molten interior of the earth, similar to those which find vent by volcanoes. Such gases, prevented by local circumstances from escaping, may, it is thought, thus shake the solid ground over a large tract, and even cause it to rise to a certain extent above its former level. The most striking proof which has been adduced in support of this doctrine, is the effect of the earthquake which took place in Chile in 1822. This is the part of that continent in which volcanoes are most numerous and active. On the occasion referred to, a shock was felt along the coast for more than 1000 miles. The land for 100 miles along the coast, and backwards to the line of the Andes, was raised above its former level. At the shore, and for some distance along the bottom of the sea, the rise was three or four feet; so that rocks formerly submerged, and covered with shell-fish, were now exposed above the sea. Old beaches, similar to that now raised, have also been observed in parallel lines along the coasts of Chile and Peru, ranging, according to Mr Darwin and M. Von Tschudi, from 20 to 120 feet above the ocean.

It has since been observed that old beaches, similar to those in Chile, exist in the neighbourhood of many seas. Along the Firth of Forth, in Scotland, there is one very conspicuous about twenty-five feet above the present level of the sea, and which generally appears as a terrace at the base of a bank a few hundred yards back from the present shore. In the Firths of Clyde and Cromarty, and indeed in every place along the British coasts favourable for their preservation, similar beaches, from twenty-five to several hundred feet above the present sea-level,

can be traced. They may always be detected by their terrace-like level, and by the presence of rounded pebbles, gravel, sand, and in some instances sea-shells, such as usually compose beaches at the present day. In some places, old beaches have been conspicuous enough to become objects of popular wonder. In the vale of Glenroy, in Inverness-shire, as also in some neighbouring vales connected with Glenroy, there are three terraces along the sides of hills, at the successive heights

Terraces of Glenroy.

of 872, 1085, and 1165 feet, which the ignorant people of the district firmly believe to have been roads formed by the hero Fingal for hunting, but which are now shewn pretty clearly to have been the shores of quiet estuaries or arms of the sea, similar to many which still exist in the Scottish Highlands. Among the Alps, in Spain, France, Norway, in North and South America, and indeed in almost every region which has undergone a narrow inspection, there are vales marked in exactly the same way as Glenroy.

The existence of a force which *gradually elevates* the land in many places out of the water was discovered by Sir C. Lyell. His chief observations were made upon the shores of the Gulf of Bothnia, which he ascertained to have risen several feet in the course of the last century, and a few inches even since 1820.

Besides the greater elevating causes arising from subterranean fires, there are some lesser ones of less mysterious origin. The sands deposited on beaches are sometimes blown by winds in upon the land, covering the vegetable soil throughout a large space, and in some instances forming hills of considerable height and magnitude. Some parts of the coast of Holland are thus fenced with ranges of sand-hills, the whole mass of which has been blown back from the sea. On some parts of the French coast, large tracts, once smiling with cultivation, are thus buried under a sterile layer of sand, which is continually advancing, notwithstanding every effort of man. On the coast of Moray, in the north of Scotland, a district once forming the barony of Culbleen, has been transformed into a sandy tract since the fifteenth century.

In various parts of the world, new land is elaborated by the efforts of coral polypes. The works of these creatures are seen upon a vast scale in the Pacific, where whole ranges of islands are formed by them. On the coast of New Holland, there is a coral reef which stretches out to 1000 miles in length. The polypes do not commence their laborious operations at a great depth below water; from 60 to 100 feet is considered the utmost extent to which the coral extends downwards. Many of these islands are of a circular or oval shape; hence the opinion that corals build upon the rims and in the craters of submarine volcanoes. The outer wall of the building emerges first above the waves, enclosing a pool of tranquil water. The seeds of vegetables are either brought there by sea-birds, or wafted by the ocean, and the islands soon become clothed with a mantle of green. The substance of which these islands and reefs are composed is lime, which the polypes secrete from the sea-water, and cement together with a glutinous matter contained in their bodies. Sir C. Lyell, while surveying the Isthmus of Panama, detached a quantity of these animals, and placed them on some rocks in a shallow pool of water. On returning to remove them a few days afterwards, he found they had secreted stony matter, and had firmly attached themselves to the bottom. To such *organic* agencies of elevation as the coral animalcule, may be added the growth of shell-beds, the formation of peat, and other accumulating vital forces which contribute to the solid material of the earth's crust.

CHARACTERS AND POSITIONS OF ROCKS.

CLASSIFICATION.

It results from the various forces thus at work throughout a succession of ages, that some parts of the dry land are seen to be composed of crystalline or other rocks, of igneous origin, while others are strata—slaty, sandy, or limestone beds—which once constituted the bottoms of seas. Another readily traceable result is the change of most of the latter rocks from their original horizontal position to various degrees of inclination, and even to an entirely vertical arrangement, or to wavy and undulating forms. That one bed or set of beds should be mainly argillaceous in its character, and another sandy; or that one should be chiefly of quartz, while another is pure lime, has depended on various physical laws: as, for instance, a simple one causing light to be transported further than heavy materials; or else upon chemical laws, producing certain elections of materials out of watery solutions. Always, however, the rule holds good, that the inorganic materials of any sedimentary rock have been derived from the solid forms of rocks which previously existed. Each mass of aqueous origin, on its being elevated into dry land, has become a source of materials for new rocks. This brings us to the general fact, that there is a chronology in rocks. The uppermost of two beds is necessarily to be presumed as having been the latest formed. Accordingly, the order of *superposition* throughout the whole series, is also the order of *age*. If this be true of one bed lying *conformably* above another, it is still more strikingly inferred where, against one group of rocks tilted up at a high angle of inclination, there rest the edges of another group lying comparatively horizontal, as it then becomes evident that between the deposition of the two groups there had been an upheaving force at work, turning up the first formed beds. In general, the shapeless masses of the igneous rocks form mountains. Against these, rest the oldest sedimentary rocks, also assuming mountainous forms, and usually at high angles of inclination. Against these, in turn, more recent rocks usually rest *unconformably*, more horizontally, and composing lower and more level ground. Now, any one bed or group of beds may be wanting in particular districts; but whatever sedimentary rocks are *anywhere* present, they are *always* found in a determinate order, being that of their age.

An attendant circumstance is, that remains of plants and animals which lived in the seas where the rocks were formed, as likewise relics of other plants and animals which flourished on the neighbouring dry land, are imbedded, and to some extent preserved, in the rocks; forming so far a memorial of the state of life on the globe at each successive period which the rocks respectively represent.

In this exhibition of ancient life there are some remarkable general facts. None of the species, scarcely any of even the genera, now exist. There is a progress from humble to higher forms throughout the whole series, ending with mammalia, but excluding man. The earlier the age, the more widely diffused are particular species over the globe. The vegetable forms generally indicate a greater luxuriance than what now exists, and shew that certain lands had then a higher average temperature than they now enjoy.

The remains of certain species of mollusca and other marine animals being found in certain rocks, fossils come to be a means of ascertaining the position of rocks in the series.

In the accompanying figure, we see a mass of igneous and unstratified rock constituting a mountain, with a

Unstratified. Stratified.

series of sedimentary beds leaning against it in a position which shews that the rise of the mountain has tilted them up. Against their broken ends, again, rests a second and undisturbed series of beds. The line between the two sets of beds is a break of conformity; the later rocks are said to be *unconformable* to the older. Such breaks are generally regarded as marking periods of volcanic violence, when the surface underwent considerable changes. What had been for ages a sea-bottom, was then perhaps raised into the open air in a disturbed and distorted state, and possibly continued to be dry land for a series of ages. Afterwards sunk once more under the waves, new beds were formed upon or against it, containing, as usual, the remains of the plants and animals which existed at the time of their formation. It is evident that, if such a series of events took place, there was an interval of time with no representation of life—namely, that during which the lower mass of strata constituted dry land. Such really appears to have been the course of this strange history. After any great break of conformity, there is usually an extensive renewal of fossils, shewing that a long space of time had passed, during which organic life was considerably changed, but of which we have only this negative memorial.

A group of beds, starting from one point of non-conformity, and ending at another, constitutes what is called a *system*. It may be considered as chronicling the state of things on the surface of the globe during a particular era. There are thirteen or fourteen such systems, presenting in whole a great mass of positive knowledge respecting the ancient history of the globe, and yet leaving probably far larger spaces of time wholly unchronicled. Systems of strata are, again, massed into more comprehensive groups called formations, of which there are only three or four. To systems, the geologists of different countries give designations, usually taken from the name of some leading rock, as the old red sandstone or the coal, or else from the name of some province in their own country where the rocks of the system are conspicuous. Formations usually are designated as Primary, Secondary, Tertiary, or with a regard to the comparative antiquity of the life commemorated by them, as Palæozoic, Mesozoic, Cainozoic.

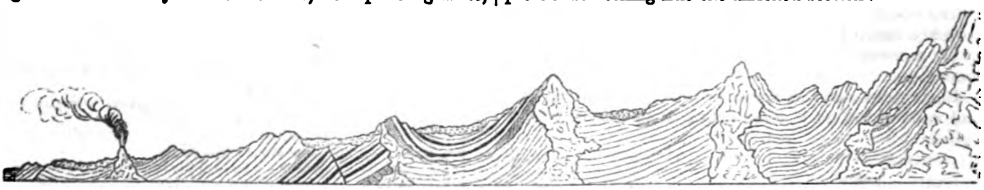
In the following table, the rock-systems recognised and described by English geologists are given, together with the more comprehensive groupings.

		SUPERFICIAL.	SOIL—decomposed vegetable and animal substances, with earthy admixtures.
			ALLUVIUM—deposits of sand, gravel, and clay, formed by the ordinary action of water.
			DRIFT (once called *Diluvium*)—a deposit of compact clay, mixed with boulders; the result of glacial action.
CAINOZOIC.	TERTIARY.		CRAG—calcareous conglomerate of marine shells and gravel; beds of marl.
			FRESH-WATER, OR ESTUARY BEDS—consisting of marls, imperfect limestones, and clays.
			MARINE BEDS—consisting of blue and plastic clays, thin beds of sand, lignite, &c.
MESOZOIC.	SECONDARY FORMATION.	*Chalk System.*	CHALK—soft and white, with layers of flint; chalk, hard, and without flints.
			GAULT, or beds of bluish marly clays, with green-sand.
			GREEN-SAND—beds of green ferruginous sands, with chert nodules.
		Oolitic System.	WEALDEN GROUP—beds of clay, argillaceous limestones and sands.
			OOLITE—beds of oolite limestone, calcareous grits, sands, and clays, all calcareous.
			LIAS GROUP—bluish clays, alum shales, marls, and limestones, all finely stratified.
		New Red Sandstone System.	SALIFEROUS MARLS—variegated shales and shell limestone, with bands of sandstone.
			RED SANDSTONE GROUP — fine-grained, sometimes conglomerate.
			MAGNESIAN LIMESTONE— thick-bedded limestones and calcareous conglomerates.
PALÆOZOIC.		*Carboniferous System.*	COAL-MEASURES—alternating beds of coal, shale, ironstone, and sandstone.
			MOUNTAIN LIMESTONE—thick-bedded, grayish limestones and shales.
			CALCIFEROUS SANDSTONES — white, thick-bedded sandstones, and calcareous shales.
		Old Red Sandstone System.	YELLOW SANDSTONES, with beds of mottled shales and marls.
			RED SANDSTONES—sometimes fine-grained, sometimes quartzose and conglomerate.
			GRAY OR RUSTY-COLOURED SANDSTONES—micaceous, and often in flags or thin-bedded.
	TRANSITION.	*Silurian System.*	LUDLOW ROCKS, generally argillaceous.
			AYMESTRY LIMESTONE.
			WENLOCK LIMESTONES AND SHALES.
			MAYHILL GROUP—sandstones.
		(*Lower Silurian?*)	CARADOC SANDSTONE.
			BALA LIMESTONE.
		Cambrian System.	ARENIG SLATE AND PORPHYRY.
			TREMADOC SLATE, LINGULA FLAGS.
			LONGMYND ROCKS.
	PRIMARY.	*Clay-slate System.*	CLAY-SLATE—finely laminated; dark, liver, and purplish coloured.
			HORNBLENDE AND CHIASTOLITE SLATES—finely laminated.
		Mica-schist System.	CHLORITE SLATES — greenish - coloured slates, with mica, mica-schist, talc-schist, crystalline limestone, and quartz rock.
		Gneiss System.	GNEISS ROCKS—intermingled with irregular beds of quartz rock, crystalline limestone, and mica-schist.

The reader must be guarded against supposing that the stratified rocks always occur in full and complete succession, as represented above: all that is meant is, that such as do anywhere occur are invariably in this order. Hence arises a practical maxim of great utility—namely, that *wherever any of these rocks occur, no example of those higher in the series is to be looked for at that spot.* At Durham, magnesian limestone occupies the surface; in Fife, the coal-measures; in Forfarshire, the old red sandstone. It would therefore be a waste of labour to dig for coal in Forfarshire, for oolite in Fife, or for chalk at Durham.

The unstratified or igneous rocks occur in no regular succession, but appear amidst the stratified without order or arrangement, heaving them out of their original horizontal positions, breaking through them in volcanic masses, and sometimes overrunning them after the manner of liquid lava. From these circumstances, they are in general better known by their mineral composition than by their order of occurrence. Still, it may be convenient to divide them into three great classes—*granitic*, *trappean*, and *volcanic:* granitic being the basis of all known rocks, and occurring along with the primary and transition strata; the trappean, of a darker

and less crystalline structure than the granitic, and occurring along with the secondary and tertiary rocks; and the volcanic, still less crystalline and compact, and of comparatively recent origin, or still in process of formation. This division of the igneous unstratified rocks subserves many useful purposes in geology, at the same time that it is a distinction warranted by the nature, aggregation, and aspect of their component minerals. The *granitic*, so named from their distinctly granular and crystalline texture, comprise granite, syenite, serpentine, porphyritic, and other varieties of granite. The *trappean* (Swedish, *trappa*, a stair) are so called from the step-like or terraced sides of the hills formed by these rocks, which include basalt, green-stone, clinkstone, trachyte, amygdaloid, &c. The *volcanic*, as the name implies, are those products discharged by recent or active volcanoes, such as lava, scoriæ, pumice, and tufa. As associated in the crust of the earth, the unstratified and stratified rocks would present something like the annexed section:



Tertiary. | *Secondary.* | *Transition.* | *Primary.*

In the above section, the UNSTRATIFIED ROCKS appear in hills and irregular disrupting masses, from the older granite to the active volcano; while the STRATIFIED occur in their regular order of succession. The *Primary* slope from the side of a lofty granitic mountain, at a high angle, and in bent or contorted strata; the *Transition* lie between the ranges of less elevated mountains; the *Secondary* occupy a still less elevated position, the Mountain Limestone being raised up on the hillside, with the Coal-beds thrown into basin-shaped hollows, or broken up by faults, and the Magnesian Limestone and Chalk rising up into slight eminences; the *Tertiary* in basin-shaped strata; and the *Superficial Accumulations* occur either as sandy downs by the sea-shore, or as drift, with boulders, overlying the earlier formations. The reader will perceive how the Tertiary strata are said to be above the Coal-measures, though they do not overlie them; and how the Coal-beds are above the Transition Rocks, though removed from each other by a wide extent of country.

ROCK FORMATIONS AND ORGANIC REMAINS.

PRIMARY.

Granite.—Granite may be described as an igneous rock, generally forming a basis or bed for all the other rocks—rising in some places from its unmeasured depths into chains of lofty hills—and in other places penetrating in veins through superincumbent rocks, and partially covering them. It composes a considerable portion of the mountain-ranges of Cornwall, Cumberland, Wicklow in Ireland, and the Scottish Highlands. The Alps, the Pyrenees, the Dofrefeld, the Abyssinian and other ranges in Africa, and the Andes in South America, are all more or less composed of rocks partaking of a granitic character.

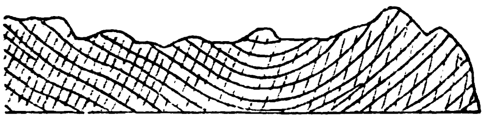
Three substances usually enter into the composition of granite—namely, 1. *Quartz* or silex, a whitish glassy substance, composed of oxygen in union with the metallic base, silicium; 2. *Felspar*, also a crystalline substance, but usually opaque, and coloured pink or yellow, composed of silicious and clayey matter, with a small mixture of lime and potash; 3. *Mica*, a silvery glittering substance, which divides readily into thin leaves or flakes, and consisting principally of flint and clay, with a little magnesia and oxide of iron. In some granites, instead of mica, we find *hornblende*, a dark crystalline substance, composed of alumina, silex or flint, and magnesia, with a considerable portion of the black oxide of iron. Such granites are called *Syenite*, from their abundance at Syene in Egypt. Other varieties are—*Serpentine*, in which there are dark spots like those on the skin of the snake (hence the name), and *Porphyry* (from its reddish colour), of which the distinguishing peculiarity is its containing little angular pieces of felspar enclosed in the mass. Any igneous rock containing such fragments, distinct from the common mass, is said to be *porphyritic*.

Primary Series.—Above the granite, in its ordinary position, lies a series of beds, consisting mainly of two kinds of rock—gneiss and mica-slate—with alternating strata of hornblende rock, quartz rock, eurite, talcose slates, chlorite slates, and argillaceous slates; of all of which it may be said that they follow no very determinate order. The lowest of these rocks are of the same materials as granite, in a very slightly modified form, and they are nearly as crystalline in their texture. Geologists also find in many places that the granite *passes* into them—a term expressing a blending of the characters of rocks at the line of their junction. Little room is left to doubt that the inferior stratified rocks were formed from the materials of the granite, disintegrated by mechanical or chemical means, and washed into the beds of vast seas, where, on their deposition, they were reached by the high temperature of the interior, and thereby reconsolidated in a crystalline form. To account for the rocks composed exclusively of one of the materials of the granite, we may suppose, as has been stated, some chemical separation of those materials.

The most prevalent rock of the series is *gneiss*, a compound, like granite, of quartz, felspar, mica, and hornblende, and so highly crystalline as to be sometimes scarcely distinguishable from granite. A great portion of the Highlands of Scotland is composed of strata of gneiss, of vast thickness. *Mica-slate* or *mica-schist*, the next most prevalent rock of the series, is composed of mica and quartz. It is the surface-rock of many extensive tracts of country. *Quartz rock*, which we may suppose to have been formed by a chemical separation of that component of granite, is also a prevalent rock. Humboldt takes notice of a mass of it in South America, more than 9500 feet in thickness. The round white pebbles or 'candy' stones, so often found on sea-beaches and in the beds of rivers, are pieces of quartz rock. *Eurite*, of which felspar is the main ingredient, and *hornblende* rock, the chief element of which is signified by its name, may also be accounted for by a chemical origin.

Clay-slate is the geological term for the well-known stone with which houses are roofed. It is, as its name imports, composed mainly of clay—a substance too liberally diffused amongst the ingredients of granite, to admit of any wonder as to its being found in a nearly distinct state in this rock. Mica-slate and clay-slate are *fissile* in their structure—that is, capable of being split into very thin plates: hence the utility of slate as a material for covering houses. But a curious diversity exists in this respect between mica-slate and roofing-slate. In the former, the *cleavage*, or direction in which it splits, is in the same line as the stratification; but in roofing-slate, the cleavage is always more or less transverse. What makes the latter circumstance the more remarkable—when strata of roofing-slate are found, as often happens, contorted or wavy, the direction of the cleavage is in one straight line through them all, indicating that the influence which produced the

cleavage in that rock took effect after the whole had been laid down, and after, by some subsequent accident of pressure, they had been forced into a wavy direction.



Section Exhibiting Lines of Cleavage in Clay-slate.

Probably this phenomenon owes its origin to electric or magnetic agency. Clay-slates are found in great abundance in Cornwall, Wales, Cumberland, and the Scottish Highlands. A fine kind makes the slates used at school, and from a kind still finer are cut the pens used for writing on school-slates.

In the *Primary* series there occur a few small beds of limestone, sometimes called *Crystalline* or *Saccharine Limestone*, from its resemblance to refined sugar, and sometimes *Primitive Limestone*, from the period of its occurrence in the series. In Greece and Italy, this rock has been subservient to the development of national talents, the highest that have ever been known of their class, for it is the marble from which the works of the Greek and Italian sculptors have been formed. In the geological history of our globe, its first appearance in the ascending series of rocks is an event of no small consequence; for limestone strata form a large proportion of the superior formations, and the manner in which they have been formed has engaged much attention. Limestone is the *carbonate of lime;* that is, a combination of the earth lime (itself a union of the metal calcium and oxygen) with carbonic acid (this being, again, a union of oxygen with the elementary substance carbon). Carbon is the largest element in the composition of vegetable and animal substances, and this its first appearance in the structure of rocks, is of course a point of much interest, more especially as it is generally concluded that many of the superior limestone strata have been entirely formed of animal remains. We are thus tempted to surmise that the formation of the primary limestone-beds marks some early and obscure stage of organic existence on the surface of our planet. No distinct remains of plants or animals have indeed been found in the series; and it is customary to point to the next upper series, in which both do occur, as the dawn of organic life. Yet many geologists are of opinion that the primary rocks might have contained such remains, though the heat under which the rocks seem to have been formed may have obliterated every trace of such substances. This series constitutes in most regions the great depository of the metals—gold, silver, tin, copper, &c.—which occur in irregularly intersecting veins, composed of ore-stone differing in composition from that of the containing strata. (For opinions as to the origin and character of metalliferous veins, we must refer to the article—METALS AND METALLURGY.)

TRANSITION.

Cambrian and Silurian.—All the rocks hitherto described are of crystalline texture, and, apparently, chemical phenomena have attended their formation. In the group now arrived at, we see little besides the traces of mechanical origin and deposition; but still a few strata resembling the preceding occur throughout the lower parts of this series, as if the circumstances under which the earlier rocks were formed had not entirely ceased. Hence the term *transition*, as implying a passing from one state of things to another.

The rocks forming the lower part of this group—termed *Cambrian* from their forming a large part of the surface of Wales—are an alternation of beds of chlorite, talcose, and other slates, resembling those of the primary series, with beds of clayey and sandy rock, of apparently mechanical origin, and thin beds of limestone, in which a few fossils are found. It thus appears that the cessation of the chemical origin of rocks, and the commencement of organic life, are events nearly connected; and it has thence been surmised that the temperature of the earth's surface was now for the first time suitable to the production and maintenance of organic things. At the same time, the alternation of the rocks teaches us the instructive fact, that the change was not direct or uniform, but that for some time the two conditions of the surface superseded each other. This is conformable with a general observation which has been made by Sir H. De la Beche—namely, that however sudden changes may have taken place in particular situations, a general change of circumstances attending rock formations is usually seen to have been more or less gradual. The few fossils found in this part of the series are, as far as ascertained, the same, or nearly so, as those of the superincumbent Silurian.

The Silurian group—so called from its being very clearly developed in that district of country between England and Wales which was inhabited by the ancient *Silures*—consists of arenaceous and slaty rocks, of evidently mechanical origin, intermixed with numerous beds of limestone and calcareous shales. The general composition of the series indicates its having been formed of a fine *detritus* (matter washed from other rocks), and its having been deposited slowly; although, as in the case of the inferior group, the arenaceous beds occasionally pass into coarse conglomerates. The limestones are less crystalline than those of the primary series; the arenaceous beds are also less silicious, and more closely resemble ordinary sandstones; while the abundance of organic remains justifies their arrangement into a separate system.

The lower transition rocks form the immediate surface in many large districts in Scotland, England, France, Germany, and North America, shewing that at the time of their formation 'some general causes were in operation over a large portion of the northern hemisphere, and that the result was the production of a thick and extensive deposit, enveloping animals of similar organic structure over a considerable surface.' The igneous rocks associated with the transition series are chiefly granitic; effusions of trap making their appearance only among the later strata. Perhaps the most extensive and gigantic efforts of volcanic power were exhibited at the close of this period; and there is abundant proof that all the principal mountain-chains in the world were then upheaved. The Grampian and Welsh ranges, the Pyrenees, Harz Mountains, Dofrefeld, Uralian, Himalaya, Atlas range, Mountains of the Moon, and other African ridges, the Andes, and Alleghanies—all seem to have received their present elevation at the close of the transition period.

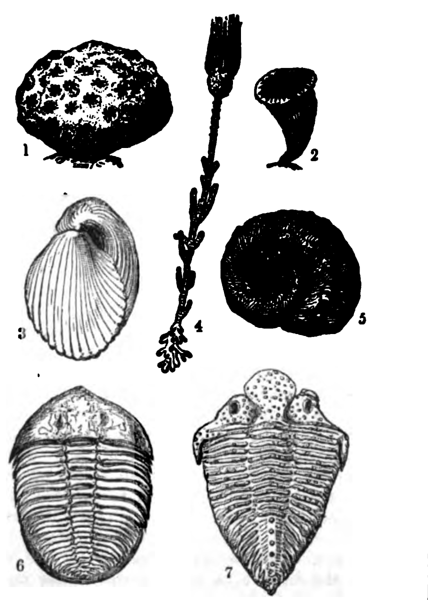
Transition Fossils.—If we are to judge of the organic life of this early period from the evidence of the fossils actually as yet discovered in its strata, we should say that it was of a comparatively humble kind. Throughout an immense range of its rocks, below the highest, there are no appearances of fresh-water or land plants, and none of vertebrate animals. In the Cambrian rocks, as limited by Sir R. I. Murchison to those below the Bala limestone, only one or two polypes, mollusks, and crustacea have been as yet, and these very recently, found. In the Bala, Caradoc, and Wenlock rocks, no true examples of fish have been discovered. That vertebrate form makes its first appearance in the Ludlow rocks.

There is a great break in the character of the fossils between the Caradoc and Mayhill rocks, greater in America than in England; and hence the opinion of some geologists that the Bala and Caradoc should be regarded as not Lower Silurian, but as Cambrian. Taking, however, the whole range as Silurian, Lower and Upper, what is the character of life presented? It is exclusively marine. The plants are a few algæ; the

animals are marine, and, excepting at the top of the series, invertebrate.

There is abundance of those creatures (*polypi*) resembling plants, which fix themselves on the bottom of the sea by stalks, and send forth branch-like arms for the purpose of catching prey, which they convey into an internal sac, and digest. At present, these creatures abound in the bottoms of tropical seas, where they live by devouring minute impurities which have escaped other marine tribes, and thus perform a service analogous to that of earthworms and other land tribes, the business of which is to clear off all decaying animal and vegetable matter. But the class of animals found in greatest numbers in this series of rocks are mollusks, possibly because the remains of these creatures are peculiarly well adapted for preservation. Among the radiata or rayed animals, the *crinoid* or *encrinite* family occur for the first time, these differing from other corals in the self-dependent nature of their structure, their fixed articulated stalk and floating stomach, furnished with movable rays for the seizure and retention of their food. As we ascend in the Silurian group, the shell-fish become more numerous and distinct in form; *spirifers*, *terebratulæ*, and *productæ*, are everywhere abundant; and *cephalopoda*, like the existing nautilus, begin to people the waters. These last were the chief destructive animals of the period—the police which kept down the swarms of lower life around them. Some of them were of gigantic magnitude, and, with their tenacious wide-spreading tentacula, must have been truly formidable creatures. It is nevertheless to be remarked, that the cephalopoda of this epoch are of a lower grade of structure than those which afterwards came into existence.

Of the crustacea of this era, the most interesting and abundant type is the *trilobite* (three-lobed), of which several genera and many species have been described, and to which scarcely any existing creature bears an analogy. The trilobite (see fig.) was a true crustacean,



1. Astrea; 2. Turbinolia Fungites; 3. Leptæna Lata; 4. Actinocrinites; 5. Euomphalus Rugosus; 6. Trilobite—Asaphus de Buchii; 7. Trilobite—Asaphus Tuberculatus.

covered with shelly plates, terminating variously behind in a flexible extremity, and furnished with a head-piece composed of larger plates, and fitted with eyes of a very complicated structure. It is supposed by some to have made its way through the water by means of soft paddles, which have not been preserved; and by others, merely to have sculled itself forward by the aid of its flexible extremity. Of its various organs, the most interesting is the eye, of which several specimens have been obtained in a very perfect state. This organ, according to fossil anatomists, is formed of 400 spherical lenses in separate compartments, on the surface of a cornea projecting conically upwards, so that the animal, in its usual place at the bottom of waters, could see everything around. As there are two eyes, one of the sides of each would have been useless, as it could only look across to meet the vision of the other; but on the inner sides there are no lenses, that nothing may, in accordance with a principle observable throughout nature, be thrown away. It is found that in the serolis, a surviving kindred genus, the eyes are constructed on exactly the same principle, except that they are not so high, which seems a proper difference, as the back of the serolis is lower, and presents less obstruction to the creature's vision. It is also found that in all the trilobites of the later rocks the eyes are the same. This little organ of a trivial little animal carries to living man the certain knowledge that, millions of years before his race existed, the air he breathes, and the light by which he sees, were the same as at this hour; and that the sea must have been in general as pure as it is now. If the water had been constantly turbid or chaotic, a creature destined to live at the bottom of the sea would have had no use for such delicate visual organs.

A few fragments of fish, ascribed to four species, named *onchus*, *plectrodus*, &c., occur in the Ludlow rocks, forming, as it were, a dawn to the full development of this class of animals in the next rock system.

LOWER SECONDARY.

The Old Red Sandstone System, as indicated by the name, is chiefly arenaceous, presenting a succession of sandstones alternating with subordinate layers of sandy shale. The sandstones pass, in fineness, from close-grained fissile flags to thick beds of conglomerate, the latter being composed of pebbles from the size of a hazel-nut to that of a man's head. The whole system is tinged with the peroxide of iron, the colours ranging from a dark rusty gray to brick-red, and from a mottled purple and fawn shade to a cream-yellow. There are some calcareous beds in the system; but these are not regularly developed, and are all silicious and concretionary in their composition and texture. Taken in the mass, the composition of this system is sufficiently indicated by the term *old red sandstone*—the epithet 'old' being applied to distinguish it from another series of red sandstones which occurs above the coal-measures, and is usually designated the *new red sandstone*.

The development of this system in a district of Western England has occasioned its receiving the subordinate name of *Devonian;* but it is much more largely exhibited along the east coast of Scotland, around the primitive rocks forming the Highlands. The laminar sandstones quarried at Arbroath and in Caithness for various useful purposes, are a noted portion of the system.

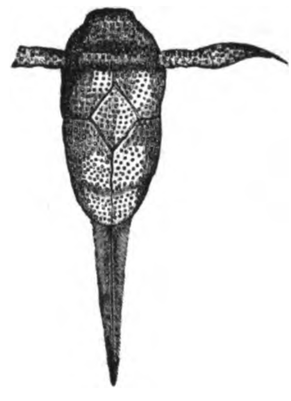
The Devonian fossils comprise an abundance of zoophytes and mollusks. The crustacea are diminished. Fishes come in great numbers upon the scene. In an upper bed, the remains of a reptile have been found, being the dawn of that superior order. The fishes form the most remarkable feature of the system. Nearly a hundred species are described, all being of the cartilaginous order, and therefore of a lower developmental type than the orders which afterwards came into existence. There is, however, much to engage attention in the curious external plates which in them make up for the softness of the skeleton.

One remarkable group, at first sight, resemble crustacea more than fishes. The internal skeleton has been so slight, that no trace of it has ever been found. To

make up for this weakness of internal framework, the surface of the body has been entirely covered with bony plates. Three remarkable forms, one comprising wing-like appendages, are here depicted.

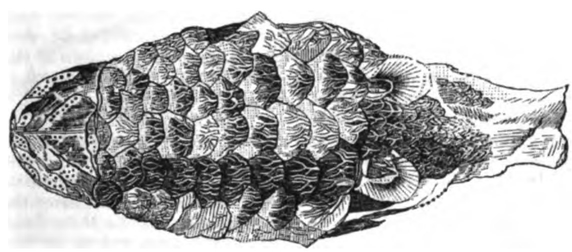
Cephalaspis.

Coccosteus.



Pterichthys.

In the *holoptychius* and some others, the bony covering is formed of a greater number of plates, finely enamelled and curiously sculptured, while the general outline more closely approximates to that of the existing fishes. In



Holoptychius Nobilissimus.

other genera, the plates pass by gradations into bony scales, regularly arranged so as to join or overlap each other. This structure is well illustrated by the *osteolepis*, which presents the form of a perfect fish, furnished with pectoral, abdominal, and caudal fins. Some families of these early fishes are furnished with spiny fins, or are otherwise armed with detached spines from two to five inches in length, and which are known to geologists by the term *ichthyodorulites*.

Carboniferous System.—This is a very extensive system, comprehending not only the coal-measures proper, from which it takes its name, and which consists of alternating strata of coal, shales, sandstones, ironstones, &c., but embracing also the mountain limestone, which always underlies the coal group, and which, in turn, comprehends alternations of limestone, shales, sandstones, and imperfect coal-beds.

Mountain Limestone—so called from its being generally found flanking or crossing the trap-hills which intervene between the old red sandstone and the coal-measures—is an abundant rock. It is frequently traversed by beautiful veins of calcareous spar, and many valuable veins of lead-ore are associated with it in Britain and elsewhere. It is of various colours, but mostly gray, varying in intensity of shade. Its associated rocks are principally calcareous sandstones and shales, abounding in organic remains, corals, encrinites, &c., which point to a marine origin.

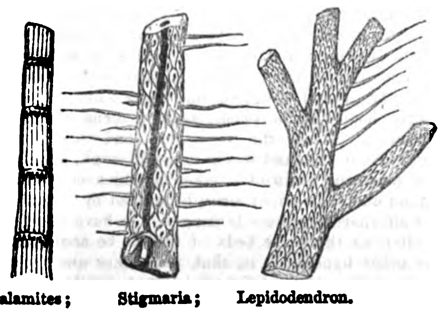
The superior group more particularly called *Carboniferous*, and variously termed the *Coal-measures*, is composed of beds of that mineral, often very numerous, alternating with beds of sandstone, shale, limestone, ironstone, and some other substances. As many as forty beds of coal exist in the neighbourhood of the town of Newcastle. The great utility of this mineral as a domestic fuel, and in the arts, gives it a high importance; and happy is the country in which it exists in any considerable quantity. In a merely geological point of view, it is equally important. This rock is entirely a mass of vegetable matter, which has accumulated in certain situations, and afterwards been covered over, pressed upon, and converted by bituminous fermentation into several varieties of coal.

Two hypotheses have been advanced respecting the circumstances under which coal was formed. According to one, the vegetable matter must have grown in dense forests and jungles for many years; then the land must have sunk, and become the basin of a lake or estuary, in which situation rivers would wash into it mud and sand, which would cover over the vegetable mass, and form superincumbent beds of shale and sandstone respectively. Then the ground would be once more elevated, or sufficiently shoaled up to become again a scene of luxuriant vegetation. When the vegetation had again become accumulated, the land would be again sunk, and become once more the basin of a lake, in which case the beds of mud and sand might again be formed by rivers. And this alternating process is supposed to have taken place as often as there are beds of coal to be accounted for. The other hypothesis is, that, into lakes and estuaries, rivers coming from different quarters would bring the various matters forming the strata of the carboniferous group—a river from one direction bringing the mud which would form shale, another from another direction the vegetable matter which would form coal, and so on,

each deposit perhaps taking place through the efficacy of some local circumstances, while the causes for the other deposits were temporarily suspended. Both theories are beset with difficulties, and perhaps the true solution is to be found in a combination of the two. Estuary and lake deposits, inundating rivers, a high temperature, a prolific Flora, and frequent elevations and subsidences of the land, seem to have been the conditions under which the coal-measures were deposited.

Fossils of the Carboniferous Group.—In this group of rocks several hundred species of plants have been discovered, all of them now extinct. About two-thirds of them are ferns; the others consist of large *coniferæ* (allied to the pine), of gigantic *lycapodiaceæ*, of species allied to the *cacteæ* and *euphorbiaceæ*, and of palms. Most of these plants probably exist in the coal-beds, forming, in fact, their sole composition; but the peculiar nature of this mineral renders it difficult to detect them by examination. Thin slices, however, have been examined by the microscope, and the vegetable structure has then been detected where no external trace of it was visible. In cannel-coal, a kind peculiarly compact, the vegetable structure is observed throughout the whole mass, while the fine coal retains it only in small patches, which appear, as it were, mechanically entangled. Splint and cannel coal often bear distinct impressions of plants. The plants are such as grow in hot moist situations; and it is therefore presumed that a climate of that nature existed at an early period where coal is now found, even in Melville Island, which is within the polar circle.

Large fragments of trees are often found in the shale and sandstone beds of the carboniferous group—more frequently in the former than in the latter. As usual with fossil substances, they are converted into the material in which they are imbedded, but preserve all their original lineaments, except that they are generally changed from their original round to a flattened form, the result of the pressure they have sustained. In most instances, these fragments of trees appear to have been transported from a distance, and laid down horizontally in their present situation; but some have been found with their roots still planted in their native soil of mud, and the stems shooting upwards through several superior beds of various substances. Even in some coal-beds there are found stems of trees in their original vertical position—the roots being imbedded in shale beneath. In these instances we must suppose the fossil to be on the spot where the living tree sprung, grew up, and died. In the Bensham coal-seam in the Jarrow coal-field, a few years ago, there was found an upright tree of the kind called lepidodendron, thirteen and a half feet wide at the base, and thirty-nine feet high, the branches at the top being also entire: the lepidodendron is so called from the scaly appearance of its stem, the scales being the roots of the leaf-stalks (see fig.). Various fossil trees have been discovered in

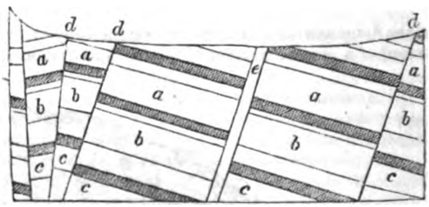


Calamites; Stigmaria; Lepidodendron.

the sandstone-beds of the carboniferous group at Craigleith and Granton, in the county of Edinburgh. One found in Craigleith Quarry was twenty feet long, three feet in diameter, with scars where the branches had been torn off, and was ascertained, by microscopic inspection of slices of the trunk, to have been a conifera, of the existing genus *Araucaria*.

The animal remains of the carboniferous group consist of zoophytes (corals, encrinites, &c.) in vast profusion, of shell-fish, crustacea, and fishes. In the mountain limestone the crinoidea seem to have attained their meridian, for whole beds, many feet thick, and square miles in extent, are almost wholly composed of them; hence the not unfrequent term *Encrinital Limestone*. Shell-fish, univalve, chambered, and bivalve, also abound; the trilobite, and crustacea allied to the modern *chiton*, are by no means uncommon; and fishes of a gigantic size and sauroid structure are scattered throughout the strata both of the mountain limestone and the coal-measures.

Intimately connected with the carboniferous system, are numerous intrusions of igneous rocks, shewing that it was an era of much volcanic disturbance. The sedimentary beds are from this cause much broken up and dislocated, as may best be comprehended by a study of the annexed figure. Here *d*, *d*, *d*, indicate what are called *slips* or faults; *e* is one of these containing an



Dislocations of Coal strata.

intrusive vein or *dike* of trap; while the other letters shew the original relations of the strata now torn away from each other.

New Red Sandstone System.—This series of strata, lying above the carboniferous system, comprehends rocks called the *red conglomerate*, formed of pieces of earlier rocks, some rough, some smoothed by rolling, all caked together; *magnesian limestone*, abounding in Germany and the north of England; *red* or *variegated sandstone*, a group of many varieties of colour, and principally of argillaceous and silicious consistence; *muschelkalk*, a limestone varying in texture, but most frequently gray and compact—not found in Britain or France, but occurring in Germany and Poland; and *variegated marls*—beds of different colours, red, blue, and gray, composed of the remains of shell-fish.

To these also belong beds or masses of *rock-salt*, of which many exist in England, particularly in the county of Chester. Rock-salt is a crystalline mass, forming irregular strata, sometimes of the thickness of several hundred feet. It is believed to be the residuum of evaporated estuaries. The substance is rarely pure, but generally contains some portion of argillaceous oxide of iron, which gives it a red colour. It is dug like coal and other minerals, and when dissolved and subjected to proper purification, is sold for domestic purposes.

Fossils of the New Red Sandstone Group.—The vegetable remains of this group belong to the same families as those of the coal strata, only they are found very sparingly and of diminished dimensions; but in the department of animal life, when we arrive at the muschelkalk or shell-limestone, we find a great difference, leading to a supposition that at this era of geological chronology circumstances had arisen changing the character of marine life over certain portions of Europe; that certain animals abounding previously, and for a great length of time, disappeared never to reappear, at least so far as we can judge from our knowledge of organic remains;

and that certain new forms of a very remarkable kind were added.

The new creatures were of such a class as we might expect to be first added to the few specimens of fish which had hitherto existed: they were of the class of Reptiles—creatures whose organisation places them next in the scale of creation to fish, but yet below the higher class of animals which bring forth their young alive and nourish them by suck (mammalia). The reptiles, which first begin to appear in the muschelkalk, continued to flourish while a great succession of other rocks was in course of deposit: throughout the whole of the Secondary Formation there were few other land-animals.

UPPER SECONDARY.

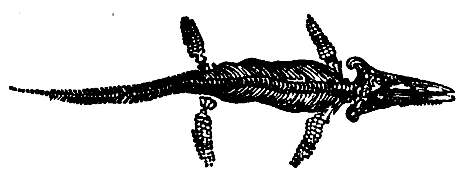
Oolitic System.—After the deposition of the new red sandstone, a further change was effected upon the general conditions of the globe, so as to produce not only an entirely different set of strata, but also different races of plants and animals. In most districts, the red sandstones and magnesian limestone were upheaved, to form new land, while portions of the former dry land were submerged beneath the ocean. By this process of elevation and depression the courses of previous rivers would be altered, former seas circumscribed and rendered more shallow, plants and animals subjected to a new distribution, and thus a different set of deposits would necessarily ensue. Instead of magnesian rocks we have dark argillaceous and oolitic limestones; for variegated saliferous marls we have blue pyritous clays; and instead of red and mottled sandstones, yellow calcareous grits. All this points to a new epoch in the terrestrial conditions of the world; and to the system of strata thus deposited geologists apply the term *oolitic* (Gr. *oon*, an egg, and *lithos*, a stone), from the resemblance which the texture of many of the beds bears to the roe or eggs of a fish. The system in England comprises three well-defined groups; namely, the Lias, the Oolite proper, and the Wealden clays—all of which are less or more developed in other parts of the eastern hemisphere.

The *Lias*, the lowest group in the system, is composed of dark argillaceous limestones, bluish clays, and shales. As indicated by the name (*lias*, corruption of *layers*), the limestones are finely stratified, and have evidently been deposited in tranquil waters. The *Oolite* is more varied in its composition, consisting of oolite limestones, calcareous conglomerates, yellowish sands and clays, all more or less calcareous. The peculiar rounded grains which constitute the oolitic texture consist either entirely of lime, or of an external coating of lime collected round minute particles of sand, coral, shells, &c.; the grits are composed of sand, lime, fragments of shells and corals; and many of the clays present the same brecciated texture. The *Wealden group* (from the *wealds* or *wolds* of Kent and Sussex, where the deposit prevails) consists of beds of bluish clay, argillaceous limestones, impure oolites, and ferruginous sandstones. Fossil plants are abundant; and, as may be expected from this circumstance, local traces of coal are not unfrequent.

The *organic remains of the Oolitic system* are very numerous, and have long attracted the attention of geologists. They shew a decided advance upon pre-existing races, inasmuch as insects, amphibious reptiles, and mammalia make their appearance in the Animal Kingdom; while new tribes of vegetables, such as the cycadeæ, liliaceæ, &c., are added to the former Flora. The organisms of the lias, the oolite, and the lower members of the wealden, indicate the marine origin of these deposits; those of the upper weald an estuary character, from the comminglement of fresh-water with marine species. With this distinction, the Fauna and Flora of this epoch may be thus summarily detailed:—*Plants*—sea-weeds; a few equisetums; many ferns allied to those of the coal-measures; cycadeæ allied to the existing cycas revoluta and pine-apple; coniferæ resembling the yew and pine; besides liliaceæ and other undescribed genera. *Animals*—zoophytes, more like existing species than those of the mountain limestone and silurian rocks; crinoidea, chiefly the pear-shaped encrinite pentacrinite; star-fishes resembling the common ophiura and asterias; echinida (sea-urchins), of which the cidaris is one of the most beautiful and abundant; shell-fish, both bivalves, univalves, and chambered; annulosa like the common serpula and land-worm; crustacea resembling the lobster tribe; insects like the beetle and dragon-fly; fishes, chiefly with enamelled scales; reptiles allied to the tortoise, to the crocodile, and gavial of existing rivers, but differing widely in their external forms and modes of existence; mammalia, two or three specimens of small marsupial animals allied to the opossums, and one bird. In the upper or fresh-water wealden there are no zoophytes or marine mollusca; but there are, according to Phillips, various land-plants, fresh-water bivalves and univalves, some fishes, sauroid animals, and remains of turtles, both fresh water and marine.

The reptiles of this early age were peculiar both in size and in structure. Some, which inhabited the seas, resembled lizards, but were of gigantic size; others, designed for land as well as sea, resembled the crocodiles which still exist in warm climates.

One of the most remarkable kinds (genera) has received the name of *Ichthyosaurus* (Fish-lizard), of which seven species or varieties have been discovered. The head is like that of the crocodile, composed of two long slender jaws, provided with a great number of teeth (in some cases 180), and eyes of great size (in one



Skeleton of the Ichthyosaurus.

instance, the cavity for the eye has been found to measure fourteen inches), while the nostril, instead of being near the snout, as in the crocodile, was near the anterior angle of the eye. The body was fishlike, arranged upon a long spiral column, which consisted of more than 100 joints, and to which a series of slender ribs was attached, and terminating in a long and broad tail, which must have possessed great strength. The whole length of some specimens of the ichthyosaurus was about thirty feet. Instead of the feet with which the lizard and crocodile are furnished, the ichthyosaurus had four paddles like those of the whale tribes, fitting it to move through the waters in the manner of those animals. It had also a construction of the sternum or breast-arch, and of the four paddles, similar to that found in the ornithorhynchus, an aquatic quadruped of New Holland, and evidently designed, as in the case of that animal, to enable it to descend to the bottoms of waters in search of food. While the ichthyosaurus, then, is mainly allied to the lizard tribes, it combined in itself the additional characters of the fish, the whale, and the ornithorhynchus.

The internal structure and the modes of living of the ichthyosaurus have been in a most unexpected manner made clear by the discovery of the half-digested remains of animals found within them or in their neighbourhood. It appears that the creature possessed a large stomach, extending throughout nearly its whole body, and that it lived upon fish and other reptiles, including its own kind. It must have occasionally devoured creatures several feet in length. Masses of the excrement of the ichthyosaurus, petrified as hard as the finest marble, and well known to geologists under the name of

coprolites (literally, dung-stones), are found to be marked spirally, like the voidings of certain species of sharks and dogfish, the intestinal gut of which winds greatly, in order that it may take up the least possible room. We thus obtain a distinct idea of the nature of a very important part of the bodily economy of this long extinct race of animals. The stomach occupied so large a space in their bodies for the reception of large quantities of food, and it was at the same time so necessary that the speed of the animal in pursuit of prey should not be clogged by a very large or long body, that the smaller intestines had been, by a wise arrangement of nature, reduced nearly to the state of a flattened tube, coiled like a cork-screw around itself; 'their bulk being thus diminished,' says Buckland, 'while the amount of absorbing surface remained nearly the same as if they had been circular.'

The name *Plesiosaurus* is applied to another highly remarkable reptile of gigantic size which inhabited the world before the days of mammalia. A particular species has been described as having a body and paddles which bore some resemblance to those of the ichthyosaurus, the former being more bulky, and the latter longer and more powerful. At the end of a long neck, like the body of a serpent, was a head resembling that of a lizard, but also partaking of the characters of the head of the crocodile and ichthyosaurus. The tail was short. The backbone of this creature, and the neck and tail continuing it, contained in all about ninety vertebral pieces, thirty-three of which composed the neck; and the vertebræ are found to be of a less fishlike structure than those of the ichthyosaurus, and not nearly so well calculated for rapid motion. The plesiosaurus probably lived chiefly on or near the surface of the water, breathing the air, and dabbling for prey like a duck or swan, but might also be able to descend to the bottom, and even to move, though awkwardly, upon land.

Of the crocodile family, found in abundance in this class of rocks, the *Iguanodon* may be cited as a specimen. It was a huge animal, resembling the present iguana of South America, which chiefly lives upon plants and seeds. The smallest part of the thigh-bone of an iguanodon was found to be twenty-two inches in circumference, and much larger than that of any existing elephant. Species resembling the present gavial of the Ganges have also been found. It may fairly be inferred from the present habits of the gavial and other kinds of crocodiles, that at the time when the extinct species flourished, the world must have contained many low shores and savannas, fitted for the residence of such creatures. Some parts of England are thus proved to have had at one time shores of lakes and estuaries resembling those of the Ganges, the Nile, and other waters in hot countries, and consequently a much higher temperature than at present.

But perhaps the greatest wonder of the reptile age was the creature called the *Pterodactyle*. Mainly a reptile of the lizard kind, its body possessed some of the characteristics of the mammalia: it had the wings of a bat, the neck of a bird, and a head furnished with long jaws, full of teeth, so that in this last part of its organisation it bore some resemblance to the crocodile. Eight species of the pterodactyle which have been found vary from the size of a snipe to that of a cormorant. The eyes were of enormous size, apparently enabling it to fly by night. From the wings projected fingers, terminated by long hooks, like the curved claw on the thumb of the bat. These must have formed a powerful paw, wherewith the animal was enabled to creep or climb, or suspend itself from trees. It has been conjectured that the pterodactyle would chiefly live on flying insects, of which, it is important to notice, several varieties existed at the same time, their remains being found in the same rocks. And it is likely, from the size of the eyes, that it searched for prey by night as well as by day. But it has also been argued, from the great length and strength of the jaws, and the length of the neck, that the pterodactyle did not live solely upon flies, but likewise sought for fish in the manner of our own present sea-birds.

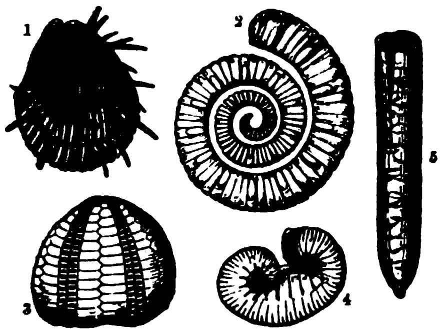
Tortoises also existed during this and the preceding age, as is proved by the marks of their feet (technically, *Sauroidichnites*) on beds of sandstone, as well as by their remains. As yet, few animals of a higher class had appeared upon earth—the remains of certain creatures of the Opossum family, found in the oolite at Stonesfield near Oxford, exhibit at the utmost the dawn of mammalian life. With, then, flocks of pterodactyles flying in the air in pursuit of huge dragon-flies; gigantic crocodiles and tortoises crawling amidst the jungles of low, moist, and warm shores; and such monsters as the ichthyosaurus and plesiosaurus swarming in estuaries; while the waters of the ocean were peopled by infinite varieties of fish; we can form some faint idea of what sort of world it was while the strata between the coal and the chalk formations were in course of being deposited.

Cretaceous or *Chalk System*.—Immediately overlying the wealden, and forming the upper portion of the secondary formation, occurs a set of calcareous, argillaceous, and arenaceous strata, distinguished in Europe as the Cretaceous System, from its containing the well-known mineral *chalk* (Lat. *creta*). In this system the arenaceous members are no longer sandstones, but loose unsolidified sands; the argillaceous beds are generally soft and marly clays; and the calcareous, instead of compact or crystalline limestones, present that soft earthy texture which prevails in chalk. All this attests a comparative recentness of formation, apart from great pressure, long-continued chemical action, or the indurating effects of heat. The strata occupy very limited spaces, and being decidedly of marine origin, point more to detached and inland seas as the areas of their deposit than to the shores or bays of the ocean. Being thus, as it were, a local deposit, and of a thickness not exceeding 800 or 900 feet, the chalk has been more thoroughly explored than any of the older systems, and its fossils more rigidly compared with existing species. Upon investigation it has been found that it embraces three well-marked groups—namely, the *Green-sand*, the *Gault*, and *Chalk*.

The *Green-sand*, which forms the lower division, is so named from its prevailing green colour, which it owes to a chloritous silicate of iron. In England, they are usually divided into the Lower and Upper green-sands, because of a bed of soft bluish marly clay which occurs about the middle of the group. The *Gault* or *golt* (a local term) overlies the green-sand, and is not of great thickness, nor very regular in its occurrence. It is a bluish chalky clay, interstratified with layers of green-sand, and holds irregular balls of clay, ironstone, and iron pyrites. The *Chalk*, which forms the upper group of this system, is too well known to require description. It consists chiefly of carbonate of lime, has an earthy texture, and is so soft as to yield to the nail. Though generally white, it sometimes passes into a dusky gray, or even red colour; and where it has come in contact with igneous rocks, it is indurated, and of a crystalline texture, like that of statuary marble. In England, the chalk strata average from 600 to 800 feet in thickness, and are usually divided into the lower and upper beds; the former being more compact, of a dusky white, varied with green grains, and containing few flints—the latter being a soft white calcareous mass, with chert nodules and regular layers of flints. Traces of stratification are scarcely distinguishable in the mass of the chalk, but are clearly evinced by the lines of flints and other nodular concretions.

The organic remains found in the system are eminently marine. There are very few *plants*, and these chiefly of marine types, such as algæ, confervæ, and other sea-weeds. Rare fragments of ferns, cones of coniferous trees, cycadites, and dicotyledonous wood, have been

detected in the green-sand; but, generally speaking, there is no formation so destitute of terrestrial organisms as the chalk. Among the *animal remains*, sponges, corals, star-fishes, annulosa, univalve, bivalve, and chambered mollusca, crustacea, fishes, and reptiles, are found in abundance; but, with one exception, mammalia are not known in the cretaceous rocks. The same races which appeared in the oolite, appear also in the chalk, but of very different genera; so much so, that it has been observed that the cretaceous system contains genera never found in any rocks more ancient or more modern. The following are characteristic fossils:



1. Plagiostoma spinosum; 2. Hamites intermedius; 3. Galerites albogalerus; 4. Scaphites striatus; 5. Belemnites mucronatus.

TERTIARY.

The Tertiary Formation comprises all the *regular strata* of limestone, marl, clay, sand, and gravel, which occur above the chalk. Before the labours of the celebrated Cuvier and M. Brogniart, these beds were regarded as mere superficial accumulations, not referrible to any definite period. Now, however, they are recognised as constituting a distinct formation—differing, on the one hand, from the cretaceous, not only in its mineral composition, but in the higher order of organisms which it contains; and on the other, from the superficial sands and clays, in being regularly stratified, and in imbedding the remains of animals distinct from existing races. In general, the strata are loosely aggregated, are of no great thickness, and present appearances which indicate frequent alternations of marine and fresh-water agencies. Thus marine remains are found in some beds, while others contain exclusively land animals and plants, and fresh-water shells. The whole suite being less consolidated than any of the secondary systems, and containing plants and animals approaching to existing forms, it presents a freshness of aspect which serves to distinguish it from older deposits; at the same time the regularity of its deposition prevents it from being mistaken for any mere alluvial accumulation. In general, it occupies very limited and detached areas, as if it had been formed in shallow inland seas and estuaries to which the waters of the ocean at times had access, and where at other periods fresh-water inundations prevailed. Another essential difference between the tertiary and the more ancient formations consists in the fact, that the latter maintain a wonderful uniformity in their composition and character all over the globe; whereas the former present almost as many distinctions in composition as there are areas of deposit. For this reason it is impossible to give a description applicable to all tertiary strata; those of England and France, however, may be taken as types sufficiently characteristic.

The following is a descending section of the Paris basin, according to Cuvier and Brogniart:

5. Upper Fresh-water Group—marls, marly sands, shelly limestone, and silicious or *burr* limestone.
4. Upper Marine Group—marls, sands and sandstones of a white or ochraceous colour, and loosely aggregated; thin layers of limestone.
3. Lower Fresh-water—marls, gypsum (sulphate of lime,) with bones of animals, and silicious limestones.
2. Lower Marine—consisting principally of a coarse sandy limestone (*calcaire grossier*), with calcareous marls and layers of greenish sand.
1. Plastic Clay Group—consisting of bluish plastic clays, with layers of sand, beds of lignite, and rolled pebbles. Supposed to be of estuary origin.

Although a very different succession takes place among the tertiaries of the south of England, yet there is sufficient resemblance in the position and aggregation of their strata, as well as in their organic remains, to establish the fact that they belong to the same epoch as the rocks of the Paris basin. The annexed section shews the order of their occurrence to the south of London:

4. Bagshot Sands.
3. London Clay—of a dull gray, or blue, or ochraceous colour; often full of green grains. Septaria and other ferruginous nodules occur in some parts. Numerous fossils.
2. Plastic Clay and Sands—sands of various colours, with occasional beds of lignite; also layers of sandy clay, with or without shells.
1. Sands—green and ferruginous, accompanied by flint pebbles, oyster-shells, &c.

In other parts of England the order of occurrence is somewhat different. It may be stated, however, in general terms, that the sands are most extensively developed: the clays chiefly in the southern basins; while at Oxford, Ramsholt, &c., the upper beds consist of a coarse conglomerate of corals, sand, pebbles, shells, &c., locally known as the 'Crag,' and so calcareous in some places as to be used as a limestone. As with the Paris and English deposits, so with other tertiary basins in Europe; those of Southern France, Spain, Italy, Austria, Hungary, &c.—all shewing an irregular succession of clays, sands, marls, lignite (wood-coal), and gypsum, which, when examined in relation to their positions, modes of aggregation, and fossils, are clearly referrible to the same period of formation.

As developed in Europe, the tertiary system spreads over wide areas, all remarkable for their conformation and connection with the outline of existing seas. Indeed, were the islands and continent of Europe to be submerged to the depth of 600 or 800 feet, the waters of the German, Baltic, English Channel, and Mediterranean seas would cover most of the tertiary strata; shewing that, with the exception of the general elevation which raised them into dry land, there has been comparatively little subterranean disturbance since the time they were deposited.

Igneous rocks are not found in connection with the tertiaries of England, though subterranean movements have thrown them into anticlinal ridges and basin-shaped hollows. In the south of Europe the case is otherwise, and the geologist finds in the igneous discharges of Auvergne, Switzerland, the Rhine, Hungary, the Caspian, and Italy, a link which connects the traps of the secondary period with the products of recent and active volcanoes.

The organic remains of the system constitute its most important and interesting feature. The fossils of earlier periods presented little analogy, often no resemblance to existing plants and animals; here, however, the similitude is frequently so complete, that the naturalist can scarcely point out a distinction between them and living races.

From their relative position, and from the organic remains contained in them, geologists have been enabled to distinguish in the tertiary series of strata four great eras of deposit. To the oldest of the tertiary eras the term Eocene is applied; the second is called the Miocene period; the third, the Older Pliocene; and the fourth and latest, the Newer Pliocene—names founded on the respective proportions which their fossil shells bear to shells of existing species. In each of these periods is included a great fresh-water as well as a marine deposit. Of the animals which flourished in each

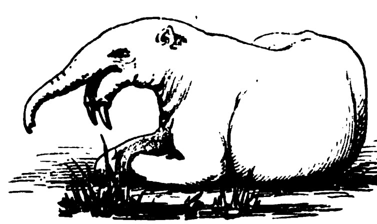
of these periods, we shall endeavour to give some account —premising in reference to the vegetable world, that the fresh-water beds have yielded cycadeæ, coniferæ, palms, willows, elms, and other families exhibiting the true dicotyledonous structure.

After the chalk formation, a period of considerable repose seems to have ensued, during which a large portion of the existing continents, and in especial the hollows and basins on their surface, appear to have been the site of vast lakes, rivers, and estuaries. From these was deposited the first great fresh-water formation of the Eocene period. While this deposit was going on, the globe was tenanted only by such quadrupeds as live beside rivers and lakes. Nearly fifty extinct species of mammalia, chiefly of this character, were discovered by Cuvier in the first Eocene fresh-water formation. The most of these belonged to the order Pachydermata (*thick-skinned* animals), of which the elephant, the rhinoceros, the hog, the tapir, and the horse, are remarkable existing examples. The extinct animals to which we now refer resemble the tapir more than any of the other Pachydermata. Among these extinct creatures, the most worthy of notice are the Palæotherium, the Anoplotherium, the Lophiodon, Anthracotherium, and one or two other families, including, some of them, not less than eleven or twelve distinct species. These mammiferous families had some general traits of resemblance, and the description of the great *Palæotherium* (ancient wild beast) may afford an idea of the main features of all. This animal was about four feet and a half in height to the wither, and somewhat squat and clumsy in its proportions. On each foot were three large toes, rounded, and unprovided with claws; the upper jaw was much longer than the under. The tapir, and partly also the hog, if large enough, would closely resemble the great palæotherium. 'The palæotheria,' says Buckland, 'probably lived and died upon the margins of the then existing lakes and rivers, and their dead carcasses may have been drifted to the bottom in seasons of flood.' The other mammiferous families of the first Eocene formation were all, like the palæotheria, herbivorous, and had, it is probable, similar habits.


Palæotherium.

The number of animals, aquatic and terrestrial, whose remains are found in the other deposits of the Eocene period, is immense. In some gypsum quarries of that era, scarcely a block can be opened which does not disclose some fragment of a fossil skeleton. The following list of the animals found in the gypsum quarries of Paris, will shew sufficiently how very different from the gigantic reptiles of the secondary eras were the creatures that tenanted, and found fitting sustenance on, the earth during the Eocene period. Besides various extinct pachydermatous families, there were extinct species of the wolf and fox, of the racoon and genette, among the carnivorous tribes; of the opossum; of the dormouse and squirrel; nine or ten species of birds, of the buzzard, owl, quail, wood-cock, sea-lark, curlew, and pelican families; fresh-water tortoises, crocodiles, and other creatures of the reptile class; and several species of fishes: all of these animals, be it remembered, being *extinct species* of existing families, exclusive of the pachydermatous animals and the fishes, which were extinct species of *extinct families*. The fossil shells found in the Eocene formations number many hundreds. As in the case of the terrestrial creatures, few of these shell-fish are of recent or existing species, not more, at the utmost, than three and a half in every hundred. We do not, moreover, recognise in the strata now under consideration those prodigious accumulations of *microscopic* shells, as they are called from their extreme minuteness, that distinguish the formations of the secondary or preceding ages. One small piece of rock, of the ages in question, has been found to contain above ten thousand chambered shells, though the whole weighed only an ounce and a half. In fact, great beds of secondary limestone seem to be almost wholly composed of microscopic shells. Such phenomena are not presented in the Eocene or subsequent tertiary deposits. The shells of these periods, as has been already observed, approximate more to the character of recent or existing species.

The second or Miocene period, however, of the tertiary ages, brings us a step nearer to the existing condition of things. Whereas only three in the hundred of Eocene fossils were of recent species, of the Miocene shells we find eighteen in the hundred to have existing representatives. Along with the mammalia, also, of the Eocene period, we find that the Miocene deposits present us with the earliest forms of animals existing at the present time. In Dr Buckland's Bridgewater Treatise, a table is given exhibiting the animals found at Darmstadt, in a bed of sand referrible to the Miocene period. In this list are mentioned two skeletons of the dinotherium, a large herbivorous animal; two large tapirs; calicotherium—two large tapir-like animals of this name; two rhinoceroses; hippotherium, an animal allied to the horse; three hogs; four large cats, some as large as a lion; the creature called the glutton; agnotherium, allied to the dog; and an animal allied to the bear. From this list the reader will perceive the gradual approach in the Miocene animals to existing species. The largest of the terrestrial mammalia yet discovered belongs to the period now under notice; it is the dinotherium, or gigantic tapir, already mentioned. No complete skeleton has yet been discovered; but from the bones found, Cuvier and others imagine the animal to have reached the extraordinary length of eighteen feet. The most remarkable peculiarities of its structure consist in two enormous tusks at the end of its lower jaw, and the shoulder-blade, which resembles that of a mole, and is calculated to have given the power of digging, or other free movement, to the forefoot. It is probable that this stupendous creature lived in fresh-water lakes, and had the half-terrestrial, half-aquatic habits of the walrus or river-horse.


Dinotherium.

In the Miocene period, the seas became the habitation of numbers of marine mammalia, consisting of dolphins, whales, seals, walrus, and the lamantin, or manati. Few of these animals were of the same species as those which exist at present; but the differences were far from being great or remarkable. This circumstance, as well as the considerable number of fossil shells identical with existing ones, exhibits an approach in the character and tenantry of the Miocene seas to the present state of things in these respects. The discovery, also, of true terrestrial mammalia, as the rhinoceros and hog, in the Miocene formations, shews that since the era of the gigantic reptiles a large portion of the earth's surface had assumed the condition of dry land, fit for the support of the common herbivorous creatures. At the same time, the occurrence of such animals as the dinotherium proves, as

Dr Buckland remarks, that many regions were still covered with great lakes and estuaries. It now remains to inquire into the nature and peculiarities of the animals characterising the Pliocene age, which, for convenience, has been arranged into two periods, the Older and Newer Pliocene: whereas only eighteen in the hundred of the Miocene shells were of recent species; in the Older Pliocene, from thirty-five to fifty, and in the Newer Pliocene, not less than from ninety to ninety-five in the hundred, are identical with shells of existing species. This great change is accompanied by the disappearance of the Palæotherian family and others, which formed the most striking animal remains of the periods immediately preceding. In place of these extinct species of *extinct* Pachydermatous or thick-skinned families, we observe in the strata of the Pliocene periods a vast number of remains of *existing* Pachydermatous families, such as the elephant, the rhinoceros, and the hippopotamus, though these remains belong to varieties that are now extinct. The first traces also now appear of ruminant animals—of oxen, deer, antelopes, camels, and other creatures of the same class. But though it is of importance to notice the existence of such remains in the Pliocene ages, in order to exhibit the progressive approach to the current state of things in the animal kingdom, it is in the huge and extraordinary creatures, now no longer to be seen on the face of the earth, that the interest of such an investigation as the present chiefly lies.

The enormous creature called the *Great Mastodon* belongs to the Pliocene era. Of all the fossil animals whose skeletons have been found *complete*, or nearly so, the mastodon is the largest. It is about 120 years since its remains were first discovered in America, and vast quantities of them have been since found in the same region, buried chiefly in marshy grounds. One skeleton, nearly complete, was dug up on the banks of the Hudson in 1801, and it is from this that a correct knowledge of the animal has been principally derived. In height the mastodon seems to have been about twelve feet, a stature which the Indian elephant occasionally attains. But the body of the mastodon was greatly elongated in comparison with the elephant's, and its limbs were thicker. The whole arrangement of the bony structure resembled that of the elephant, excepting in one point, which Cuvier regarded as of sufficient consequence to constitute the mastodon a different genus:—this was the cheek-teeth, which are divided on their upper surface into a number of rounded obtuse prominences, arranged not like the elephant's, but like those of the wild-boar and hippopotamus; whence it is concluded that, like the latter animals, the mastodon must have lived on tender vegetables, roots, and aquatic plants, and could not have been carnivorous. The lower jaw of the skeleton found on the Hudson is two feet ten inches in length, and weighs *sixty-three pounds!* Like the elephant, the mastodon had two tusks, curving upwards, and formed of ivory; and in the opinion of Cuvier, it had also a trunk of the same kind with the former animal's. Altogether, making an allowance for several additional feet of length, it may be considered as varying but little from the larger specimens of the elephant. From the immense number of mastodon bones which have been dug up in various parts of the earth, and particularly in the New World, we must conclude that at no distant period of time the terrestrial surface was extensively peopled by these enormous creatures.

Another creature, belonging to the later Pliocene ages, if not indeed to the era of the diluvial formation, has been discovered in America, both north and south. This is the *Megatherium* (great wild beast), an animal more widely removed in character from any existing creature than any of the other fossil remains that have been yet observed. The megatherium was discovered towards the end of the last century. A skeleton, almost entire, was found nearly at one hundred feet of depth, in excavations made on the banks of the river Luxan, several leagues to the south-west of Buenos Ayres. The megatherium was a tardigrade (slow-moving) animal, like the sloth, but of gigantic dimensions, and calculated to subsist on roots and succulents, and on the foliage and young shoots of trees, for the pulling down and uprooting of which its structure seems to have been admirably adapted.

Associated in the same set of deposits—that is, in detrital beds of somewhat later origin than the tertiaries of Europe—Mr Darwin has discovered in South America the remains of several gigantic quadrupeds besides those of the megatherium. Of these the most remarkable are —the *Megalonyx*, nearly allied to the megatherium; the *Scelidotherium*, an animal as large as the rhinoceros, but partaking of the character of the Cape ant-eaters and armadilloes; another great armadillo-like animal with a bony covering; the *Macrauchenia*, a huge beast, with a long neck like a camel; and the Toxodon, perhaps the strangest animal ever discovered. The macrauchenia is described as belonging to the same division of the pachydermata as the rhinoceros and tapir, but shewing in the structure of its long neck a clear relation to the camel, or rather to the alpaca and llama. As to the toxodon, it equalled in size the elephant or megatherium; but the structure of its teeth proves indisputably that it was intimately related to the gnawers, the order which, at the present day, includes most of the smallest quadrupeds. In many details it is allied to the thick-skinned animals; and, judging from the position of its eyes, ears, and nostrils, it was probably aquatic, like the dugong and manatee, to which it is also allied. 'How wonderfully,' remarks the discoverer, 'are the different orders, at the present time so well separated, blended together in different parts of the structure of the toxodon!'

SUPERFICIAL ACCUMULATIONS.

When the geologist has described the series of formations terminating with the highest Pliocene, it remains to him to account for the general mould of the surface, and take some notice of the accumulations of loose matter lying upon it. It is very readily manifest to him, that, since the deposition of the last genuine rock stratum and the occurrence of the last considerable volcanic disturbances, inequalities have been reduced and smoothed off, excavations have been made, and much clay, sand, and other matters has been deposited. Water and ice are called into view as agents in the production of these phenomena.

The reducing and smoothing process has been conducted on a scale far beyond what any one could have been prepared for. In districts of the primary rocks, we find the upper parts of great folds cut away, to the depth of many hundreds of feet. In the secondary rocks, where dislocations to an equal extent have taken place, instead of finding the one side rising to that height above the other, all is smooth. In many places vast cuttings have been made, which no running streams can account for. These *denudations*, as they are called, are generally thought to be the result of marine action; but it is probable that the views of geologists on this subject will yet undergo a great modification, as water does not in general leave smooth surfaces, or make great scoopings, without leaving equally great ruins behind it.

In intimate connection with the moulding process is the nature of the superficial accumulations. It is necessary to inquire what these are.

In the northern regions of both Europe and America, wherever any considerable mass of the superficial accumulations exists, it presents a variety of materials alternating in something like a uniform order. In some situations, and particularly in Scotland, there are not fewer than six beds of these various materials; it is seldom there are fewer than three. The deposit most generally found in immediate contact with the surface of the rock, is a hard compact paste of blue or ruddy clay, mixed confusedly with worn fragments of rock. In

Scotland, this is known as the Boulder Clay, or Compact Blue Clay. It is in very many places ten or twelve feet in thickness—in some as much as a hundred, or even more—but in some it is only two or three feet thick. When it is removed, we generally find the surface smoothed and scratched, as the beds of glaciers are seen to be at the present day. Its constitution indicates its being formed in circumstances of violence and confusion; but these must have been occasionally interrupted, for here and there occur in it thin beds of tranquilly deposited sand and gravel.

Resting on the boulder clay in some places is a deposit of fine silt clay, apparently the washings of the subjacent hard deposit, and well known for its serviceableness in making bricks, tiles, and earthenware. Beds of this clay alternate with beds of fine sand, and amongst them it is common in Scotland to find arctic shells, with bones of large ruminant animals and pachyderms.

Next occurs a coarse gravel, compacted with clay or with metallic oxides; altogether much resembling the rough matters left on the brink of Alpine glaciers. Over this, again, in Scotland, are further beds of fine sand and clay alternating, till we come to the vegetable soil, which is merely a mixture of the surface matter with the remains of decayed plants and animals.

The prevalent opinion regarding the boulder clay is, that it has been formed in an arctic sea charged with icebergs and packs of ice, which have passed grazingly over and worn the sea-bottoms, carrying along and finally depositing the detritus as we see it. It may be safely predicted, however, that this theory will not stand, as it is far from adequate to account for the obvious connection of the productive agent with the agency which has produced the entire mould of the country in its varieties of hill and dale. Drifting ice, it may be admitted, will graze coasts and sea-bottoms here and there, and deposit considerable quantities of detritus; but it could never work with equal force over an unequal sea-bottom, leaving large and small eminences, throughout the entire area involved, in precise proportion to the comparative hardness of the parts, as we find to be actually the case. The uniformity of the direction of the striation of the subjacent rocks over large areas—areas often most unequally moulded—is also irreconcilable with the idea of simply floating or drifting ice. The exigencies of the case demand a more hard-pressing application of the agent; an application, too, which at once affected the lowest parts of the surface, forming therein often the finest groovings and channelings, and moulded the swellings of hills of at least a secondary magnitude.

The sand-beds intercalated in the boulder clay, and the alternating beds of fine clay and sand lying above it, containing arctic shells and remains of deer, elephants, &c., indicate a period of tranquil conditions, during which this country was partially covered with an arctic sea, bordered by lands such as Siberia and Norway now are.

The coarse gravel, resembling as it does the spoils of modern glaciers, strongly suggests a time of elevation of the land, during which high valleys were filled with moving ice, the masses of which, descending to the sea and there breaking off, carried out great quantities of rough matter, which, as the process of melting went on, they distributed over the sea-bottom.

A subsequent sinking of the land may be presumed to have caused a recommencement of the process of the formation of alternating sands and gravels. There is great reason to believe that many of the larger masses of the latter material are the washed remains of the deposits formed by glaciers; but this we have no room on the present occasion to demonstrate. The superficial powdering of erratic blocks which is so remarkable in all northern regions, may very reasonably be ascribed to the transporting power of floating icebergs.

It thus appears, from the superficial accumulations, that there was a long period during which great tracts of northern land were submerged, raised, and probably submerged again. There had also been at that time a lower average temperature than at present. The general tendency of the study of this superficial formation is to shew that it represents a vast stretch of time and a considerable variety of conditions. It is tolerably certain that no great change of the relative level of sea and land has taken place in the historical era of two or three thousand years. During the time the present relative level has been maintained, however much longer than the space of the historical era, a certain cut has been made in the fabric of the land, forming the present beach. But in the west coast of Scotland, twenty-five feet above the present beach, is an ancient one much more deeply indented, and we find lying upon this elevated beach the spoils of valley glaciers, bearing evidence of subsequent marine action. Here, then, is the memorial of only one in the series of conditions exhibited by the superficial accumulations; and we clearly see that it represents a period of many thousands of years.

The latest series of geologic changes has been the rise of the land out of that deep immersion in the sea which the superficial formation evidences. We have clear proof that this emergence was not sudden and complete, but slow, and by a series of movements. This proof lies in the existence of *ancient beaches* at various elevations above the present shore. We generally detect such an object by its levelness along some considerable tract, and by the indentation of rocks, or the deposit of sands and gravels, mingled as these occasionally are with deposits of shells. All our valleys exhibit such terraces more or less conspicuously, proving that they were at one time the beds of estuaries.

Of man himself no remains have been found, save in the most recent and superficial deposits—as alluvial mud, calcareous breccia, volcanic tufa, and the like—thus proving him to be one of the latest, if not the very latest, inhabitant of this globe.

SUMMARY.

The history of the earth thus presents a long series of mineral and vital gradations, as yet but imperfectly interpreted by geology. The stratified formations, from the gneiss to the existing surface, bear evidence of these gradations, both in their composition and modes of aggregation; so also do the unstratified rocks—the granitic, trappean, and volcanic compounds—by the order in which they succeed each other. We see in these successive formations the fragments, as it were, of a history of organic being. We look in upon it, it may be said, from time to time, find that many changes have taken place in the intervals, yet always see a connection between the present and past, assuring us that the whole is essentially connected. We see, too, that a steady progress has been maintained all through, from invertebrate to vertebrate forms, from the fish to the reptile, and from the reptile to the warm-blooded animal; man finally coming upon the scene as a crowning work. It is a most interesting and elevating study, never failing, we believe, in well-ordered minds, to exalt our conception of the Divine power and excellence.

METEOROLOGY.

METEOROLOGY explains the laws which regulate weather, seasons, and climates. It involves particularly the consideration of the atmosphere—its magnitude and height above the surface of the earth; its weight or pressure and elasticity, and the gradations of these as we ascend; the materials and manner of its composition; the alterations made upon it by heat and cold; and its electrical condition. It is by an accurate knowledge of these that we are enabled to understand the nature and causes of the incessant movements and changes going on in the air around us, and of the ever-varying appearances of the sky over our head; including the phenomena of winds and storms, of rain, dew, hail, snow, mists, and clouds, and their connections with one another, and with seasons and places.

THE ATMOSPHERE.

Its Composition—General Structure—Density—Pressure.

The atmosphere is a vast ocean of invisible gaseous matter, enveloping the terraqueous globe, and extending to a considerable height. Although it cannot be seen by the eye, it is yet felt to be an inert, material mass, which resists bodies in their motion through it, and when set in motion itself, possesses momentum or impetus, like a flying ball or a running stream. Another property of the atmosphere, which proves its genuine materiality, is its weight or pressure. It presses upon the earth, exactly as the sea does, under the influence of gravitation. This pressure is in proportion to its quantity, and its natural or specific gravity. When we ascend to a great height above the ordinary level of the ground, as to a mountain-top, the pressure is diminished, because the quantity lying above becomes less. At the sea-level, the average pressure is 14¾ pounds on every square inch; it is nearly the same as the pressure of a lake of water 33 feet deep, or a lake of mercury 2½ feet deep. The construction of the barometer, or instrument for constantly measuring this weight, and shewing the degrees of its fluctuation from day to day, is explained under PNEUMATICS. By it the air is made to sustain a column of mercury, which is higher or lower according as the whole weight of the atmosphere above increases or diminishes; and therefore, by looking at the height of the mercury, we know at any instant the weight of the atmosphere at that spot.

The average height of the mercurial column is somewhat less than 30 inches at the level of the sea; but it fluctuates to such an extent, that it sometimes descends to 28 inches, and sometimes rises to 31. A low barometer proves that some cause or other has carried away a mass of air from that particular locality; and a high barometer proves that the opposite action has taken place.

The atmosphere is therefore to be considered as a mass of gaseous or aërial fluid enveloping the earth, and pressing on its surface with a weight amounting to 14¾ pounds (14·7) on every square inch. This fluid is found to be not a single substance, but a mixture of several substances, totally distinct in their properties, and serving quite different offices in the economy of nature. The two chief ingredients—nitrogen and oxygen—which make up more than $\frac{49}{50}$ths of the whole mass, are as different in their character as water and alcohol. The proportions of these two are very nearly 77 of nitrogen to 23 of oxygen by weight; that is, 100 pounds of air contain 77 pounds of nitrogen, and 23 pounds of oxygen. The nitrogen is therefore the principal element in point of quantity; but the oxygen performs the greatest variety of functions: it is the supporter of life, and the indispensable agent in combustion, in putrefaction, and in many other natural processes.

Deferring in the meantime the consideration of the other ingredients of the atmosphere, we have to study in the first place the mode of mixture of these two gases, and the general structure of the mass they compose. Although the mechanism and constitution of a gas are not apparent to our senses, yet we can infer with certainty that it is made up of atoms which keep one another at a distance by a repulsive force. From the fact that any gas can be compressed into a very small fraction of its ordinary bulk, we are sure that its particles are usually at a great distance from each other in comparison with their size. If we imagined a flight of crows, each fifty feet every way apart from the next, we should have some idea of the spread of gaseous atoms in empty space.

If we take, then, any single gas, such as nitrogen, we may be certain that its particles stand asunder from each other at very great distances compared with their size; and these distances are all equal, for the nature of the repulsion is such, that there is no rest nor stable balance if a particle is nearer its neighbour on one side than on the other. But when two gases are mixed, the circumstances are changed. We are still sure that each will repel its own kind, but we cannot say beforehand whether or not the particles of one kind will repel the particles of another kind. Experiment seems to warrant the conclusion that they do not; and therefore, when oxygen and nitrogen are mixed, it is as if we introduced among the crows, already supposed scattered at a rigid distance of fifty feet, a flock of pigeons, held apart a hundred feet from one another, but not under any repulsion from the crows; so that while the distances of each kind among themselves are equal and fixed, there would be the greatest variety of distances between pigeons and crows, from close contact to a hundred feet. Considering also the immense amount of empty spaces between the crows, the admission of the pigeons would be almost as free as if the space was altogether empty: each kind might move and expand almost as if the other did not exist.

Oxygen probably does not repel nitrogen. It is not so certain from the facts, whether oxygen and nitrogen are perfectly indifferent, or whether they have a slight attraction. There are many analogies which render it likely that strange gases may in some cases attract each other.

Taking the entire mass of the atmosphere, considered as an ocean of gaseous or elastic fluid, its density must diminish as we ascend from the earth. The tendency of air being to expand to the utmost limits allowed, it would fly off into the boundless regions of space if it were not kept on the earth by the force of gravity or by its weight. The portions at the earth's surface not only lie upon it by their own weight, but they are compressed by the weight of all that lie above them; and in consequence they are compacted into a smaller bulk than they would otherwise have. The bulk occupied by any amount of gas diminishes exactly in proportion to the weight laid upon it. Thus, if a cubic foot of air at the earth's surface—which owes its actual density to a compression of 14¾ pounds to the square inch, arising from the weight of the whole height of air lying over it—were pressed with a weight of 29½ pounds to the square inch, its bulk would be reduced to half a cubic foot; or if half the usual

weight were taken off, and the pressure reduced to 7½ pounds to the square inch, it would expand to the bulk of two cubic feet; and so on. Hence, if we ascend so high that one-half of the mass of the air would be below us, and the other half above us, the compression would be only 7½ pounds to the inch, and the air would be twice as rare as at the earth, or it would have only half the density. Two cubic feet of such air would be equal in weight to one cubic foot of air taken at the earth's surface.

The density of the air therefore diminishes upward in the exact proportion of the diminished weight of the mass. It can be determined by calculation at what heights the weight and density will be of any given amount. Thus, at 20,000 feet above the sea, the density is less than half that at the earth's surface; on the highest summits of the Andes or Himalaya, it is about one-third, or three cubic feet of air weigh no more than one cubic foot at the sea-level.

There is another cause besides the decrease of weight to affect the decrease of density—namely, the increased capacity of the rarefied air for heat. If a cubic foot of air is allowed to expand to two cubic feet, it requires to absorb additional heat into its mass in order to keep up its temperature. It is said to have acquired a greater capacity for heat; and if it do not receive an extra quantity, it will cool down, or it will have a much lower temperature than in its former state. So that the air at 10,000 feet of height will, by its expansion, require more heat to keep up the temperature; and as it has no means of getting more than the surface-air, but, in fact, receives rather less, it will be very much colder than the air below. The first consequence of this cooling is a loss of elasticity, which causes it to contract under the pressure to which it is subject, and to occupy a smaller space than it would have occupied if the temperature had been kept up by a new supply of heat. Thus a cubic foot of air, when half its pressure is taken off, becomes two cubic feet, only on the supposition of receiving so much heat as to make the two feet as warm as the one foot; failing this, it cools down, and contracts to somewhat less than two cubic feet; so that when this new cause is taken into account, the density of the air does not diminish quite so fast as the weight diminishes. The whole atmosphere is more compressed or more dense than if the law of diminished weight and density were to hold strictly; we do not require to ascend so far to pass through a certain amount of it—that is to say, we shall reach the point of 7½ pounds pressure at a lower level.

When allowance is made for the effect of the increased capacity of the air for heat, with the cold and contraction thence arising, the weights and densities of the air at different heights are as in the following table, which exhibits in the fourth column the decrease of temperature at each height, beginning at 32°:—

Height in Feet.	Barometer Column in Inches.	Density.	Temperature.
0	30·000	1·00000	32°
5,000	23·949	·82656	14·8
10,000	19·106	·68321	— 3·1
15,000	15·229	·56472	—22·4
20,000	12·044	·46677	—43·6
25,000	9·579	·38582	—67·5
30,000	7·566	·31890	—95·1

In this way the atmosphere goes on, becoming rarer and lighter, and at the same time colder, as we ascend, until it ceases altogether. At what height it actually terminates, we do not at present know; it can be with certainty affirmed to extend to fifty miles from the earth, as at this height it exercises a sensible effect in refracting light; but for anything that is known, it may extend to eighty or ninety miles. Its own elasticity would carry it away without limit, if something did not counterbalance the expansive force. But the weight of the particles, or their gravity towards the earth, serves as a counterbalance on the one hand, and on the other hand, the cooling caused by extreme rarity diminishes the force of the elastic spring; so that where the diminished elasticity is no more than a balance for the weight, there the atmosphere will terminate. For a few miles below this termination, it must be extremely rare, or little else than a vacuum. For all practical purposes, therefore, the height or depth of the atmospheric ocean is at present assumed as about fifty or sixty miles; but the great body of it is accumulated near the earth's surface. In reality, one-half of its material mass lies within three miles from the earth, and three-fourths of it within less than six miles. Its pressure on the highest pinnacles of the earth's surface is less than one-third of the whole weight as experienced at the sea-level.

MOVEMENTS OF THE ATMOSPHERE.

All the movements and changes to which the air is subject, originate, some way or other, in the application of heat. So long as an equal temperature is kept up, the air continues at rest; but the slightest addition or subtraction of heat in any part of it leads to a series of movements that may extend to a great distance all around. The nature of these movements requires to be distinctly explained.

If the temperature of the whole surface of the earth, being at first supposed everywhere the same, were to rise equally at once, the effect would be to expand and elevate the atmospheric ocean without producing any other movement. The upper surface would stand higher, and the equal divisions of the mass would also be higher. There would be no side-motions or horizontal currents created; each column would be lengthened, but its particles would remain over the same spot as before. But if we now suppose that the surface of the earth is unequally heated, as in fact it is, a new action will ensue. If two adjoining spots of ground are of unequal temperature, and communicate an unequal temperature to the columns of air lying upon them, the column which is most heated will be expanded in its whole length, so as to overtop the other, and it will be made rarer or lighter all through. Two effects will arise from this: a lateral or horizontal movement of the air from the cold to the warm column will take place *below*, according to the general law of hydrostatics that a heavy fluid buoys up a light one. But if we consider the condition of the two columns *above*, or at their upper ends, we will find that the opposite effect must arise; that is, a movement will take place from the warm column to the cold; for the warm column being to some extent lengthened or elevated, a considerable mass of it will be thrown further up than an equal mass of the cold column. Not only will the uppermost portion of the long column, which rises to a point where the short column has ended, and has therefore nothing but a vacuum to flow to, have a side-movement towards the other, but portions far beneath the top will have a pressure so much greater than the contiguous portions of the shorter column, that they too will flow out laterally, and determine a current tending to equalise the difference of heights and pressures.

When a difference of temperature exists between two spots that lie near one another, the effect of the aërial currents which take place between them is to equalise the temperature; the cold air is brought into contact with the hot ground, and the hot air with the cold ground, and gradually the heat of the one is reduced, and that of the other raised, till both become exactly the same. The air lying over them will then be the same, and all movement will cease. Thus the lateral currents arising from differences of terrestrial heat tend gradually to abolish those differences, and bring all to one uniform pitch. The air is the carrier of warmth from over-heated to under-heated localities, and moderates both extremes. Its lateral currents are the effect of unequal

heating, and in some measure the remedy. These lateral currents are felt and recognised by us under the name of *winds*. If the differences of warmth that originate them were only limited and temporary, the carrying of heat to and fro would bring about an equality, and then the air would come to a perfect repose; but these differences of warmth are perpetually kept up, and, notwithstanding all the influence of the under and upper winds, they exist to a very large amount; hence the lateral currents go on for ever without ceasing. The middle band of the earth, or the equatorial zone, is exposed to the burning radiance of a direct sun, while the two polar regions are so faintly heated, that snow never melts upon them; and this great standing inequality keeps up two grand sets of movements, which encompass the globe. The equatorial air, being warmer and lighter below than the air on each side, is buoyed up by the cold masses moving in upon it from north and south, and thus two great under-currents are maintained between the poles and the equator. The equatorial mass being expanded far upwards, overtops and overpresses the upper portions of the colder columns on each side, and therefore flows in upon them on both sides, making one movement towards the north pole, and another movement to the south pole; thus causing two great upper-currents towards the poles, while the under-currents are moving from the poles. The inequality of the equatorial and polar regions in respect of heat is thus in some degree mitigated; but it is by far too great to be entirely done away. If there were no such currents, the equator would be hotter, and the poles colder than now; but even as it is, the difference is enormous, and causes the two vast and incessant movements which we have now endeavoured to describe.

We have supposed, for simplicity's sake, that the atmosphere is divided into an equatorial and two polar masses; but in reality there is a constant gradation from the equator to the polar regions, and the movements will take place between every two adjoining portions of atmosphere of which one is further north or south than the other.

Although, as a general rule, the temperature of the earth decreases from the equator to the poles, this is not strictly or at all times true. Various causes occur to render a high latitude as warm as, or warmer than a lower, and in such a case a contradiction will arise to the general movement, which will have peculiar local consequences.

If we take the case of the heating of the air, not at the surface of the earth, or the base of an atmospheric column, but at some high elevation, a new train of consequences will ensue. Let a portion of air, from 10,000 feet upwards, receive an accession of heat, while the temperature of the portion below remains the same—the first effect will be an expansion and rising of the whole length of the column above 10,000 feet; the upper regions will have thus an increased pressure, and overflow all around. If the equatorial current is passing along these regions, it will be met and resisted by this local current, and on one side the equatorial air will accumulate unduly, and on the other side there will be a deficiency. There is here a movement created above, *without a counter-movement below*, and consequently air will be flowing away from the heated column, and no new air flowing in; hence its quantity or pressure will diminish, and the barometer, which measures the pressure, will fall.

VAPOUR OF THE ATMOSPHERE.

Vaporisation—Dew—Mist—Clouds—Rain—Hail—Snow.

Next in quantity to nitrogen and oxygen, although very small compared with these, is the vapour of the atmosphere; that is to say, the gaseous water or steam that is constantly present in it. Although very trifling in amount, this portion of the atmosphere is of immense importance in its effects. Unlike the other gases, it is easily reduced from the aërial to the liquid form, or to water as we usually find it; and it is constantly going through the processes of becoming liquid, and descending to the earth, and again rising into the air in the gaseous or invisible form. The great agency connected with these transformations is heat. When water passes into steam, it takes in a large amount of heat, which is rendered insensible to the feeling or to the thermometer; and when steam or invisible vapour is condensed into water, all this heat is given out again.

It is essential to bear in mind that true gaseous water, steam, or elastic vapour of water, which all mean the same thing, is invisible, like the other portions of the atmosphere; and that the white cloud that appears at the chimneys of steam-boats and locomotives, and at the spout of a kettle, is not gas or elastic vapour, but vapour partially condensed, whose particles only require to be brought together to become drops of water. It is, in fact, water in the form of something like dust. Mist, fogs, and clouds are of the same character: they are not gaseous steam, but precipitated watery particles destitute both of mutual repulsion and of the latent heat of steam. All visible vapour, therefore, is an intermediate state between elastic invisible vapour and water. If the atmosphere contained nothing but true steam, it would be transparent and cloudless.

The formation of steam out of water is most conspicuous in the process of boiling, where the surface is kept in an intense bubbling state, each bubble containing a mass of steam, which forces its way up into the air. This boiling takes place at 212° of the thermometer, called for that reason *the boiling-point*. The steam thus formed has an elastic force equal to the pressure of the atmosphere, or a force of 14$\frac{3}{5}$ pounds to the square inch; that is, when admitted into the cylinder of a steam-engine, below the piston, it forces the piston upwards with a power that it would take 14$\frac{3}{5}$ pounds on the square inch to balance; or a piston of ten square inches would be buoyed up as with a weight of 146 pounds. The reason for the *violent* escape of steam at 212° is, that it has attained a force equal to the weight of the atmosphere pressing on the water, and is therefore able to set aside this pressure, or make its way in spite of it. But even at temperatures below boiling, water passes into steam slowly and invisibly. It is well known that a wet surface soon becomes dry; in other words, that the water upon it disappears. Water, however, cannot be annihilated, or pass out of existence—it is impossible to annihilate any substance that has weight—in the drying process, the liquid water becomes gaseous invisible water or steam, and mixes with the other steam contained in the air. But for this disposition of water to pass into the aërial state, it would remain as permanent on a spot as paint or plaster.

The rapidity of the process of drying up, or of the passing of water into steam, depends, in the first place, on the temperature of the water. We have seen that it is abundant and violent at 212°; and it is less and less for every degree downwards. The elastic force of the steam produced also depends upon the temperature. The elastic force of steam at the boiling-point is equal to the pressure of the atmosphere; while the elastic force of steam produced silently at 80° is only $\frac{1}{30}$th of the elasticity of the atmosphere, or equal to one inch of the barometer.

Now, the entire quantity of steam that can rise is limited by the temperature in the same manner as the elasticity is limited. Water at 80° will give forth vapour, until as much has been produced in the atmosphere as would counterbalance one inch of mercury; evaporation then ceases, and the air is said to be *saturated* with steam. Whether the steam rise freely into the atmosphere, or rise into a vacuum, no more will be produced at 80° than this quantity. If the temperature were raised to 90°, there would be the means of supporting an additional quantity of steam, and evaporation

would again go on, until as much were distributed through the air as of itself would counterbalance 1·36 inches of mercury, or about $\frac{1}{22}$d of the weight of the whole atmosphere. With every new addition of heat, new evaporation would go on, which would be of the silent kind up to 212°, when the full pressure of the atmosphere would be reached. If an extensive lake were at this extreme temperature, steam would be produced from it, until as much were diffused through the air as would press upon the ground at the rate of 14¾ pounds to the square inch, or sustain 30 inches of mercury; the other air of the atmosphere and the steam together would raise the barometer to about 60 inches, which is called a pressure of two atmospheres. But as the water on the earth's surface does not rise much above 80° even at the equator, and is far below this temperature in other regions, the whole weight of vapour in the air rarely amounts to one inch of mercury; so that if the pressure due to nitrogen and oxygen by themselves were 29½ inches, the whole pressure, including the vapour, would be only about 30 inches, and at the utmost 30½ inches.

It has been stated, that at 80° vapour rises till as much exists in the air as weighs an inch of mercury; and that if the heat be increased, an additional quantity can be produced and supported. Let us now consider what must happen if the air were saturated with all that could be maintained at 80°, and if the temperature were then lowered, say to 60°. While at 80°, the vapour may amount to an inch; at 60°, it amounts only to ·52, or little more than half an inch. If, therefore, the full quantity which can subsist at the higher temperature has been produced, and if the temperature then descend to the lower point, there will be nearly half an inch too much for the reduced temperature, and this excess will be thrown out in the state of visible non-elastic vapour, or fall down as liquid drops. There will be either some kind of fog, cloud, or mist, or the aggregation of these into watery coherence.

TABLE, shewing the Elasticity of the Vapour that can be maintained at each Degree of Fahrenheit, from 0° to 90°, expressed in Inches of Barometric Pressure.

Degrees.	Inches.	Degrees.	Inches.	Degrees.	Inches.	Degrees.	Inches.
0	·061	23	·144	46	·326	69	·704
1	·064	24	·150	47	·337	70	·727
2	·066	25	·155	48	·349	71	·751
3	·069	26	·161	49	·361	72	·776
4	·071	27	·167	50	·373	73	·801
5	·074	28	·173	51	·386	74	·827
6	·077	29	·179	52	·400	75	·854
7	·080	30	·186	53	·414	76	·882
8	·083	31	·192	54	·428	77	·910
9	·086	32	·199	55	·442	78	·940
10	·089	33	·207	56	·458	79	·970
11	·093	34	·214	57	·473	80	1·001
12	·096	35	·222	58	·489	81	1·034
13	·100	36	·230	59	·506	82	1·067
14	·104	37	·238	60	·523	83	1·101
15	·108	38	·246	61	·541	84	1·136
16	·112	39	·255	62	·559	85	1·171
17	·116	40	·264	63	·578	86	1·209
18	·120	41	·274	64	·597	87	1·247
19	·125	42	·283	65	·617	88	1·286
20	·129	43	·293	66	·638	89	1·326
21	·134	44	·304	67	·659	90	1·368
22	·139	45	·315	68	·681		

When as much steam exists as can be maintained at the temperature which the earth and air have at the time, *saturation* is said to take place. Thus, at the temperature of 70°, ·727 of an inch would suffice for saturation; and at 32°, ·199, or about one-fifth of an inch, would have this effect. But if less steam is formed than could be supported at the temperature, there is said to be a certain amount of *dryness* or *thirstiness* in the air; meaning that there is room for further evaporation. Thus, if at the temperature of 65° there exists only half an inch of invisible vapour, the air is below saturation, and gives an opening for more to rise out of the water lying on the surface of the earth. The air is dry to the extent of one-tenth of an inch of the barometer; for at 65°, about six-tenths of an inch could be supported, while only five-tenths exist; evaporation may therefore go on till the additional tenth is supplied, and then the air will be fully saturated.

The degree of dryness or thirstiness can be measured by the difference between the amount of vapour existing, and the amount that might exist under the temperature. Thus, if the temperature were 40°, and the vapour a quarter of an inch, the dryness would be the difference between ·25 and ·264—which is the amount sustained at 40°—or ·014; that is, $\frac{14}{1000}$ths of an inch of the barometer. So if the temperature were 85°, and the vapour nine-tenths of an inch, the dryness would be ·9 subtracted from 1·171, or ·271, which is a little more than one-fourth of an inch. It is on the amount of this difference that the rapidity of evaporation depends, or the quickness of the process of the drying up of wet surfaces. In the case last mentioned, where the dryness is ·271, the rapidity of evaporation would be about twenty times as great as in the previous case, where the difference was ·014.

If the quantity of vapour in the air is less than what is supportable at the temperature for the time being, there is some lower temperature which this quantity would completely saturate. Such temperature is called the temperature of the *dew-point*. Thus, if there were three-quarters of an inch of vapour existing, the temperature that this would saturate will be found from the table to be 70°—the number at 70° being ·727, or very nearly three-fourths; 70° is therefore the temperature of the dew-point for this amount. It is so called because the smallest cooling below 70° would bring out visible mist, and cause dew to be formed on adjoining surfaces. The dew-point is the lowest point to which the air can be cooled down without giving out visible moisture. If the air were saturated, the temperature and the dew-point would be the same; if the air is dry, or not saturated, the dew-point temperature is below the air temperature; and the difference between the dew-point and the temperature of the air is a measure of the dryness.

The number of degrees of Fahrenheit between the air temperature and the dew-point temperature is not, however, the exact estimate of the dryness, as will be seen from the following example. Suppose the temperature of the air 80°, and the dew-point 70°, then the amount of additional vapour that could be supported would be found thus:—

Vapour sustainable at 80°, 1·001 inches.
" " 70°, ·727 inch.
Difference, . . ·274, above a quarter of an inch.

Thus a difference of 10° of temperature makes a vacancy for a fourth of an inch of vapour. Take now a difference of 10° further down in the scale. Suppose the air 40°, and the dew-point 30°:—

Vapour sustainable at 40°, ·264 inch.
" " 30°, ·186 "
Difference, . . ·078, about 1-12th of an inch.

So that a difference of 10° between 70° and 80° makes a dryness or deficiency three times as great as a difference of 10° between 30° and 40°. Water would disappear three times as fast in the one case as in the other. Hence to know accurately the dryness of the air at any time, we must reduce the difference of temperatures to barometric inches, according to the preceding table.

If vapour existed in empty space, with no other gas along with it, the quantity existing at any one time would be determined by the barometer. But as, in fact, the vapour is only a very trifling portion of the mass of gases which press upon the earth, the barometer cannot give its value separately; the mercurial column expresses

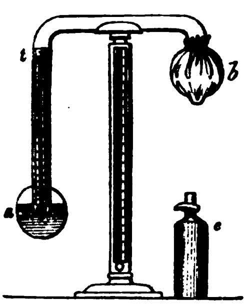
only the pressure of the sum-total of the atmosphere. Hence some other means must be adopted for finding the amount of vapour by itself. Instruments used for this end are called *hygrometers;* from the Greek *hygros*, moist, and *metron*, a measure.

Apart from instruments, we judge of the dryness of the air, or of the additional amount of vapour which it could sustain, by the time required to dry wet bodies, such as the ground, or wet clothes hung in the air. We call that a dry day which makes water disappear rapidly from all surfaces, and which keeps the air clear and transparent. On the other hand, when wet clothes are found to make no progress towards drying, we call the day damp or moist; the air in this case being saturated with vapour.

The chief instruments for determining with perfect accuracy the dryness of the air, and the actual amount of aqueous vapour that it contains—technically its *hygrometric condition*—are Daniell's hygrometer, and the wet and dry bulb thermometers.

The principle of Daniell's hygrometer is to cool the air down upon some surface till dew appear, and to mark the temperature when this happens. Thus, suppose a tumbler standing in the open air is cooled by pouring in cold water, or any other cold liquid, until the sides of the tumbler are covered with dew, the temperature of the glass at the moment that the dewing begins will be the temperature of the dew-point.

The construction of the hygrometer is as follows:—A central pillar or stalk has a thermometer attached to it, and carries across the top a glass tube, bent down at each end, and terminating in two bulbs *a* and *b;* the longest branch has a thermometer *t*, inside whose ball is the centre of the bulb *a*. The tube and bulbs are perfectly air-tight, and contain a quantity of ether, which is seen partially filling the lowest bulb. The bulb *b* is covered with muslin, and the bulb *a* is either blackened or covered with a metallic coating. The inside of the tube contains, besides the liquid ether represented around the thermometer-ball, an atmosphere of gaseous ether, which is expanded through its whole interior, and into the muslin-covered bulb *b*. Along with the instrument, there is used a small bottle of ether *e*, with a bent tube in its mouth, to allow the liquid to be poured out in drops. The instrument is placed exactly as in the figure when an observation is to be made; and the two thermometers are supposed to be both at the temperature of the air. The observer then takes up the little bottle, and drops ether on the muslin bulb. The ether being exceedingly volatile, evaporates rapidly, and cools the bulb; and this cooling has an effect on the gaseous ether within, and condenses a portion of it; which condensation leads to a fresh evaporation from the liquid ether in the lower bulb, and consequently to the production of cold within that bulb, and the cold goes on increasing in it so long as ether is dropped on the muslin. The temperature of the thermometer-bulb is thus steadily falling, and in the course of a short time it will descend to the dew-point temperature, and the outside of the bulb will become visibly dewed. The instant of the dew's appearing is what the observer has to note, and also the height of the enclosed thermometer at this instant, for the temperature of deposition is strictly the dew-point temperature. To make the observation more accurate, the bulb is allowed to become warm again, by ceasing to drop ether on the other bulb, and notice is taken of the moment that the dew disappears, and of



the enclosed thermometer at the instant; the mean of the two temperatures—the temperature of deposition and that of clearing—will accurately express the dew-point. The thermometer on the central pillar gives the air temperature at the time of the observation, and enables the observer to ascertain the dryness of the air by determining the difference of the two.

The determination of the dew-point by the wet and dry bulb-thermometers depends on the effect of evaporation in causing cold. When water passes into invisible vapour or steam, it absorbs from whatever substances it touches a large amount of heat, and consequently makes the bodies from which it rises colder as it proceeds. If the surface of a pool is giving off vapour, the remaining mass of water is made colder by the action; and if a wet cloth gives off its moisture, the cloth is cooled through the loss of the heat which the rising vapour carries off: the more intense the evaporation, the greater will the cooling be. In applying this principle to measure the humidity contained in the air, two thermometers are taken—one of the ordinary construction, which serves simply to give the temperature of the air; but the other has its bulb covered with a piece of rag, which is kept constantly wet by communicating with a cup of water by an absorbent wick. The water round the bulb will be constantly evaporating when there is any dryness in the air; and the greater the dryness, the more intense the evaporation, and consequently the greater the cooling of the bulb, from which the rising vapour derives its latent heat. Hence this moist-bulb thermometer will fall in proportion to the degree of the evaporation, or in proportion to the dryness of the air at the time. We have therefore only to compare the two thermometers—the one giving the air's temperature, and the other a reduced temperature depending on the rate of evaporation or the degree of thirstiness—in order to judge of the comparative quantity of moisture existing in the surrounding atmosphere. Tables are used along with this hygrometer for calculating the dew-point temperature, which is ascertained, without calculation, by Daniell's instrument. The advantage of the wet-bulb hygrometer is, that an observation can be made without much trouble; whereas a nice operation must be performed upon the other in order to obtain what is sought.*

The force of evaporation, or the quantity of water which is converted into invisible vapour in a given time, depends entirely upon the dryness of the air, or upon the vacancy for moisture that exists at the time; this vacancy being measured, as we have already shewn, by the difference between what might exist and what does exist. For example, it is calculated that if the air were at 60°, and the dew-point 40°, about a quarter of a grain of water would rise every minute from a surface of six inches diameter. But no calculation of this kind is

* Besides the above, there are various instruments called *hygrometers*, depending on the principle of the shrinking and expanding of bodies in relation to the degree of humidity with which they are affected. Fibrous vegetable substances, such as ropes, contract by imbibing moisture; while, on the contrary, hairs and catgut (strings of violins) contract by drought. Hair has been found to be the most delicate in hygrometrical motions. Saussure accomplished the construction of a hygrometer from a single long hair, previously cleaned in a soda lye. Various philosophical toys, as ornaments for mantel-pieces, have also been constructed to indicate the dryness and moistness of the atmosphere, all on the similar principle of contraction and expansion of a hair, piece of catgut, or part of the beard of the wild oat. One of the most useful instruments of this class is a small object resembling a watch in external appearance, designed to prove the dampness or dryness of beds: a movable hand on the dial-plate points out very speedily the hygrometrical condition of the bedclothes on which the instrument is laid. Hygrometers of the kind just mentioned, however ingenious, fail as instruments of science or of rigid comparison, chiefly from the circumstance of their liability to lose their contractile and expansive energy, as well as the difficulty of making many of them to possess similar powers.

as yet perfectly accurate, owing to the uncertain action of the wind on evaporation. The effect of a current of air, is to carry off the vapour from the surface as it rises, and leave the space free for an additional supply. The more rapid the wind, the faster every wet surface dries up. On calm, stagnant days, drying is in general a very slow process compared with its rate under a brisk wind.

If there were no other atmosphere upon the earth than the atmosphere of vapour, and if the whole surface of the earth were at 32°, the constitution of such an atmosphere, in respect of pressure and temperature at different heights, would be, according to Professor Daniell, as in the following table; in which it must be noticed that the numbers for the elasticity of vapour are somewhat different from the table given at page 36, which is taken from the one in use at Greenwich Observatory:—

Height in Feet.	Elasticity or Pressure in Barometric Inches.	Temperature.
0	·200	32°
5,000	·177	28·5
10,000	·157	25
15,000	·140	22
20,000	·124	19
25,000	·110	16
30,000	·100	13

If we compare this table with the similar one previously given for dry air, we find one striking discrepancy, and that is in the decrease of temperatures. The decrease in the vapour is very slow compared with that of the dry gas. At 5000 feet, the dry air sinks from 32° to 14°·8, or about 17°, while the vapour falls only 3½°. At 20,000 feet, the dry air is as low as —43°, or has descended 75°: at the same height the vapour has descended only 13°, or to from 32° to 19°. The same contrast is seen whatever be the commencing temperature. This disparity produces very important consequences, seeing that the two atmospheres are mixed up together.

The same relation subsists between the vapour of the atmosphere and the other two gases, nitrogen and oxygen, that compose it, which holds between these two gases themselves; that is, the particles of elastic vapour repel one another, but do not seem to repel the particles of nitrogen or oxygen; consequently, while they must keep their distance from their own kind, they may freely approach and remain near the particles of the other kinds. If the particles of oxygen are, in consequence of their smaller quantity, more widely apart than those of nitrogen, the particles of water may be supposed to be much further apart than either; for the steam in the air is but very small in amount compared even with the oxygen. We are to conceive, therefore, a very wide-spreading set of vapoury atoms moving about in a space where there also floats two other sets of atoms, both of them much more numerous than the atoms of vapour. Although there is no repulsion between the atoms of different kinds, there may, however, be an attraction: it is possible that when a particle of steam comes near to a particle of oxygen, they may cohere, and remain until something happen to separate them.

Professor Daniell has traced very important consequences to the disparity of the decrease of temperature in the two atmospheres of dry gas and vapour. We have seen, for example, that at 5000 feet the decrease of temperature of the dry air is from 32° to about 14°; and that the decrease in the steam atmosphere by itself would be only to 28°. Now as this steam at 28° exists in the midst of the air at 14°, it will necessarily be cooled down, by the influence of the cold mass, to the same pitch as the air, or to 14°; but with this cooling a precipitation must take place, for the amount of steam that could exist at 28° cannot be maintained at 14°, and all the surplus will therefore be thrown out as visible cloud, and fall downwards to the lower regions. At some still higher stratum, the same process will be again repeated; for, notwithstanding the amount thrown out at the first stage, what remains will at some high station be found too much for the surrounding temperature, and a fresh precipitation in the form of cloud will occur.

Hence it will happen that although evaporation is going on abundantly in the lower regions, and the temperature such as to sustain it in the invisible form at the earth's surface, yet when it rises upwards, it will come to some stratum too cold for it, and where, therefore, a certain portion must be thrown out of the invisible into the visible state, and cause a cloudy layer to be formed. Above this the air will perhaps be clear for a considerable way, but at a certain additional height, the same excessive coldness will occur, causing a succession of cloudy layers. The greater the dryness of the lower air, the further up will the clear region extend, or the higher will be the first place of deposition or cloudiness.

When invisible vapour, or true steam, is precipitated either into water or into the intermediate state of cloud, its latent heat is given out; that is to say, all the heat that entered into it when it first passed from water into steam. In the case of a precipitation in the upper air, all the heat is communicated to the air, and serves to raise its temperature to some extent. Now, we have seen that this is one of the cases where the upper-current of the atmosphere may be increased without a corresponding increase in the under-current, and where, consequently, the total pressure will be altered. If the air is heated and expanded in the upper regions while remaining unaltered below, the overflow or passing away of the upper air will be increased, while the influx beneath continues the same, and consequently more will be going away than there is coming in, so that the whole column will be lightened. In this case, the barometer must fall, and a corresponding rise will occur in some other places; hence a great degree of evaporation, or a very great quantity of vapour in the air, is apt to make the barometer stand low. The currents of dry air formerly mentioned do not tend to disturb the barometer; the prime cause of all its fluctuations lies in the actions of the vapour, which alter the natural gradation of temperature and pressure, by carrying heat from the surface to discharge it in the higher regions.

We must now allude more particularly to the peculiar forms of visible vapour, or the constitution of the varieties of watery substance named mist, fog, cloud, dew, hoar-frost, rain, snow, and hail. Mist, fog, and cloud are names for nearly the same thing. When there is a general haze of precipitated vapour covering the whole sky, and coming down to the surface of the earth, it is termed a *fog*. When a white smoke is seen to rise from the courses of rivers and wet land, it is called a *mist;* but mist and fog are often indiscriminately applied to the same appearance—namely, to a vapoury haze lying upon the ground. *Clouds* are the masses of haze or fog which are seen floating in the higher regions, and which do not descend to the ground.

It being well known that visible vapour, cloud, or mist is not elastic or gaseous, and therefore is not supported by its expansive force like a gas, it has been always a mystery how the clouds are kept suspended in the air. When steam is precipitated into white watery particles, they ought to fall to the ground immediately like a shower of dust; for they are no longer supported by being repelled upwards by the particles beneath them. Many explanations have been devised for this singular fact. It has been supposed that the particles of cloud are like blown bubbles, which are lighter than the air, and therefore supported like balloons. But if they were little balloons, they could hardly be so perfectly balanced as never either to float upwards or sink downwards. Besides, no man can say how such watery vesicles can come to be filled with a gas lighter than the air surrounding

them. The only explanation yet given which is consistent with the known facts, is, that the watery particles are suspended by their adhesion to particles of air. We are quite entitled to suppose that a particle of water has an adhesion to a particle of air when they encounter one another in the atmosphere, just as we are sure that water on the ground has a strong attraction for the air in contact with it, or contained within its mass. This attraction upholds the vapoury particles when they are bereft of the self-sustaining power of elasticity or mutual repulsion.

The steam of a kettle when it becomes visible, the white cloud of a steam-chimney, our breath in a moist or cold day, are all precipitated moisture or mist. Sometimes this mist is rapidly reabsorbed as it spreads out, shewing that there is a certain dryness or vacancy in the air sufficient to take it in among the invisible steam, when it is distributed over a somewhat larger surface.

If the air is exposed to a cooling, so as to bring it beneath the temperature of the dew-point, vapour must be thrown out everywhere, and a fog or mist will be formed. If, for example, the dew-point were 45°, and if a cold wind or the decline of the day were to sink the air to 32°, then all the moisture above what can remain at 32° would be made visible, and a very dense fog would be the result. In this manner are formed the dense fogs of the polar seas, the fogs found along the courses of rivers, upon the sides of mountains, and over shoals and headlands. The difference between the temperature of the water and the adjacent land affects of course the air resting upon them; and hence the development of visible vapour in these localities.

The celebrated fogs of London originate in the same way; but their black and thick appearance is owing to the quantity of smoke which is suspended in them. Water in every shape has an intense attraction for carbon; and the particles are strongly seized upon by the precipitated vapour, and detained to blacken the atmosphere. This attraction would seem to prevent the ready absorption of the fog, even in the dry air of rooms. In towns where little smoke is produced, the peculiar black fogs of London never arise. The great attraction of water for almost all substances is one cause of the disagreeable effects of mists and fogs; for the effluvia that would otherwise rise upwards and diffuse themselves, are to a great extent caught and held by the free vapour, and thus kept near the surface. In stagnant foggy days, all the odours which arise from houses and works are more perceptible than at other times.

Clouds have been distinguished by Mr Howard into several classes, according to their structure and appearance. The three principal forms are the *cirrus*, or feather-cloud, the *cumulus*, or heaped-cloud, and the *stratus*, or stretched-cloud. The *cirrus* is composed of

Cirrus.

thin threads or filaments, aggregated into woolly or feathery forms, and sometimes making a delicate slender net-work. It is the first indication of serene and settled weather, and first shews itself in a few fibres, spreading through the atmosphere. These fibres by degrees increase in length, and new fibres attach themselves to the sides. The duration of the cirrus is uncertain—from a few minutes to several hours. It lasts longer, if it appears alone, and at a great height; a shorter time, if it forms in the neighbourhood of other clouds. From its usually curling appearance, the cirrus is called in England the *mare's-tail* cloud. The *cumulus* is the kind of cloud resembling mountains piled upon mountains, and generally ends above in rounded masses, while it is horizontal

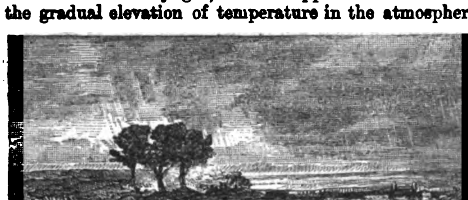
Cumulus.

below. The appearance, increase, and evanishing of cumulus, in fine weather, are often periodical, and correspondent to the degree of heat. Generally, it forms a few hours after sunrise, attains its highest degree in the hottest hours of the afternoon, and decreases and vanishes at sunset. If the upper region, with its drying power, predominates, the upper parts of the cumulus become cirrus; but if the lower region predominates, the basis of the cumulus sinks, and the cloud becomes *stratus*,

Stratus.

which appears as a long horizontal band of moderate density, with its lower surface resting upon the earth or the water. Combinations of the above forms have been discriminated under the names of *cirro-cumulus*, *cirro-stratus*, and *cumulo-stratus*. The black rain-cloud, which seems a general mixture and confusion of all the clouds in the heavens, has been called the *nimbus*.

The *cirrus* clouds are the most elevated: they have been found as high as 20,000 feet, and they must therefore be often made up of snow-particles, for even under the equator, water would be frozen at such a height. In general, we may say of the light fleecy masses that we see on a summer-day, that they are made up of snow-powder or frozen particles. The *cumulus* clouds are evidently the precipitation of the ascending vapour in the cold upper regions; for they generally increase with the heat of the day, which disperses all superficial mists. The *stratus*, on the other hand, has more the character of a night-cloud: it is a result of the cooling of the air in the evening, and comes out in the lower regions of the atmosphere. All mists and fogs are of this species of cloud, which, in its lightest state, does not wet leaves or any objects with which it comes in contact. In calm evenings, the stratus may be seen ascending from the valleys to the higher grounds, and there extending itself in masses like a fleecy mantle. It generally arrives at its point of greatest density about midnight, or between that time and daylight, and disappears at sunrise by the gradual elevation of temperature in the atmosphere.



Nimbus.

Sometimes it remains quiet, and accumulates in layers, till the atmosphere is incapable of sustaining its weight,

when it assumes the condition of the heavy and dark *nimbus*, and falls in a shower of rain.

When moisture is precipitated at night in the form of wetness and drops on the surface of the ground and on the leaves of plants, it receives the name of *dew*. This precipitation arises when the surface of any body is cooled below the dew-point temperature. Thus, if the dew-point were 45°, and if by any means a glass tumbler were cooled down to 40°, the film of air lying next to it would also be cooled down to 40°, and would therefore have to give out all the vapour which it could not hold at that temperature; but the precipitated surplus in this case would not appear as mist in the air, but would adhere to the surface of the glass. When cold glasses are brought into a warm room, they sometimes become dewed all over in this way. The bringing out of visible dew is, as we have seen, the means of determining the dew-point temperature in Daniell's hygrometer.

Night-dews are most copious when the sky is clear. The reason of this is, that the earth cools faster under a clear sky than when hung over with dense clouds, which prevent the radiation of the heat; just as bed-curtains make a bed warmer. The surfaces which naturally radiate off their heat with most rapidity are the first to sink below the dew-point temperature and to become dewed. Thus, rough surfaces are wetted sooner than smooth, plants sooner than glass, and glass sooner than metals. Metals being good conductors of heat, as fast as their surface cools, heat flows to it from the interior, and consequently the temperature of the surface cannot sink till the whole mass throughout has parted with its heat. Woolly and fibrous substances cool very fast at the surface, and are therefore rapidly bedewed. No dew can fall on a surface till its temperature has fallen below the dew-point; hence in the case of a very dry atmosphere there may be no dew formed at the coldest time of the night. In arid deserts, and in the countries where dry winds prevail, dew is not often seen.

When the surface dewed is below the freezing temperature, the vapour is not only precipitated, but is also frozen; hence the origin of *hoar-frost*, or frozen night-dew. The occurrence of hoar-frost is a proof that the temperature of the ground has fallen below 32°, as well as below the dew-point temperature. As in the case of dew, everything that prevents the radiation of heat arrests the formation of hoar-frost. During the chilly nights of spring, plants that are sheltered by trees are less liable to be frozen than those which are fully exposed; and a slight covering of straw, or even of paper or netting, will often afford an effectual protection. Vineyards, it is said, have frequently been saved from the effects of frost by enveloping them during the night in a cloud of smoke.

Rain is the aggregation of the cloudy particles into masses or drops, which can no longer be sustained by adhesion to the particles of air, and must therefore fall to the ground. Rain most usually arises from the mixture of different strata or currents of air. When a warm saturated mass is acted on by a cold mass, there is always a precipitation of vapour; and besides this, the agitation and conflict of the two currents bring the scattered particles nearer each other, so as to favour their adhesion. As the amount precipitated increases, the aggregate drops will become larger, and at last they will fall away by their own weight.

When the temperature of the stratum of air from which the rain falls is under 32°, the vapour or clouds must necessarily be frozen, and the descending particles will be *snow* instead of rain. Snow-flakes are the aggregation or union of frozen particles, just as rain-drops are the union of watery particles. They aggregate, according to the law of the crystallisation of water, into regular and symmetrical forms, of which the general character is a six-sided figure; as, for example, six needles branching from a centre, or six arms from a six-sided nucleus, each needle being three or six sided. Though single crystals always unite at angles of 30°, 60°, or 120°, they nevertheless form, by their different modes of union, several

hundred distinct varieties of snow-flake, some of which are figured in the preceding engraving. Any agitation of the air, or an increase of moisture or temperature, destroys of course their delicate and beautiful structure.

When drops of rain formed in an upper stratum descend through a stratum whose temperature is less than 32°, they are frozen into lumps or balls of ice, which we term *hail*. Hailstones are thus the consequence of an irregularity, or an exception to the ordinary and natural arrangement of the atmospheric layers: instead of the colder air being always uppermost, in this case a cold must lie beneath a warm stratum.

The precipitation of vapour in any shape, causing a vacuity, as it were, in the atmosphere, is generally accompanied with commotions and rapid movements of the air, which are called *storms*. These differ from the ordinary wind-currents in being sudden, violent, and temporary.

Besides *nitrogen*, *oxygen*, and *watery vapour*, the atmosphere contains *carbonic acid* to the amount of about a two-thousandth part of its whole weight. This is employed by nature, along with water, in supplying the food of plants; and it is given out in the processes of combustion and animal respiration. It is diffused through the other gases of the atmosphere on the principles already laid down. *Ammonia* is also a constituent of the atmosphere, but its amount is exceedingly small. These may be said to be all the permanent elements of the atmosphere, or the substances always present in it, and diffused through its whole extent.

From its contact with the earth, the lower stratum of the air usually contains a number of casual substances: such as the gaseous exhalations from animals and vegetables, living and dead; the exhalations from all chemical and organic processes, whether natural or artificial; the innumerable gaseous and volatile products of human habitations, villages, and cities; the odours and effluvia that issue from almost every spot of the earth; the sand, dust, and fine solid particles which are carried up from the surface, and floated in the winds; the seeds of numerous plants and animalcules, which, by their minuteness and lightness, are easily carried in the air; and the subtle matters that convey the poison of disease. Most of these substances, from their injurious effect on the human system, are regarded as impurities; but their consideration does not belong to meteorology.

SURFACE OF THE EARTH IN RELATION TO THE ATMOSPHERE.

Mean Temperature—Trade-winds—Sea and Land Breezes—Hygrometric Changes—Fall of Rain—Fluctuations of the Barometer and Thermometer.

The changes and fluctuations of the atmosphere have all a relation to the peculiarities of the earth's surface, and especially to the unequal heating of its different parts, owing to the varied action of the sun, the distribution of sea and land, and the different elevations of the land. The decrease of heat from the equator to the poles causes one class of atmospheric changes; the change of the sun's place in the course of the year, or the rotation of seasons, causes another class of changes; and both of these are modified by the positions of sea and land, and by the characters of the mountains, valleys, and plains of the land-surface.

The mean temperature of the equator is about 81°. If the whole earth were a perfectly smooth globe of one uniform kind of surface—that is, if it were all sea, or all

one kind of level land—the temperature would decrease steadily from the equatorial amount, according to the latitude. The mean temperature at the poles cannot be known by actual measurement; but it is inferred to be about 10°. The poles, however, appear not to be the coldest points of the globe. In the northern hemisphere there would seem to be two poles of maximum cold, about latitude 80°; the one north of Siberia, the other north of America.

By the *mean temperature* of a place is understood the average temperature for a whole year, or for a number of years. If observations were made of the temperature for every hour in the course of a day, the average of all these would be the mean temperature of the day; also the mean of the greatest and least temperatures would be pretty nearly the mean of the day. If the mean temperatures of 365 days are found in this way, and an average taken of the whole, this gives the average or mean temperature of the year. And if a great many years have been observed in the same manner, the average of the whole would be reckoned the general mean temperature of the place where the observations have been made.

The action of the sun is the chief source of the warmth possessed by the atmosphere and the ground, though not the only source. The earth itself is proved to have a permanent internal heat, which increases gradually from a point beneath the surface downwards, as far as observations can reach. But the heat that fluctuates from day to day, and which is greater in summer than in winter, and in the daytime than during the night, is derived solely from the sun; and these variations are owing to his acting more strongly at one time than at another.

The reason why the sun heats the equator and the regions adjoining more strongly than it heats the temperate and polar regions, is, that at the equator it rises higher in the heavens, and shines more directly downwards. The further away a place is from the equator, the less is the average noonday height of the sun, and therefore the smaller the influence it exerts.

The whole force of the sun's rays does not act directly on the solid surface of the earth; the atmosphere arrests a certain portion of the heat, and is itself rendered warm by the portion arrested. This is one source of the warmth of the air. When clouds are spread out in the atmosphere, the resistance to the rays is still further increased, and a greater portion taken up by the air itself. The other sources of atmospheric heat are, contact with the surface of the earth, and the radiation of heat from the ground upwards.

The air exercises a very important influence in keeping up the mean temperature of the earth, by resisting the passage of heat outwards, on the same principle that our bodies are kept warm by clothing. The thinner the covering of air, the colder would the earth be; as we see in ascending to the tops of mountains, at which the temperature is always much lower than at the sea-level—the cold increasing with the height. These high places receive a more intense solar radiation through the thin covering of air that lies upon them; but such is the ease with which the heat can radiate off through a thin atmosphere, that they are always kept comparatively cold. If we had no atmosphere at all, the rays of the sun would be very intense where they actually struck, but so rapid would be the loss of heat by radiation, that the whole earth would be permanently kept far below freezing; no liquid material of any known kind could exist on its surface.

The first great effect on the atmosphere of the unequal temperature of the different parts of the earth, and especially of the steady decrease of heat from the equator to the poles, is to produce the two grand currents which we have already described: an upper-current from the equator to the poles, and an under-current from the poles to the equator. If the earth were at rest, these currents would blow exactly north and south, but the daily revolution of the globe has an effect in altering their directions. The equator, or thickest portion of the earth's body, considered as a ball revolving on an axis, moves with the greatest rapidity in the daily whirl; any place upon it is carried round at the rate of upwards of 1000 miles an hour. But the belts on each side of the equator being smaller in circumference, any point on one of them is moved with proportionably less rapidity. Thus the belt or zone at 60° of latitude has only half the circumference of the equatorial zone, or about 12,000 miles; so that a place upon it will move round only 12,000 miles a day, or 500 miles an hour. In like manner, at 30°, the rapidity of movement is about 860 miles an hour. Now the atmosphere revolves along with the earth, and every portion of it will have the same velocity as the place on which it lies. Thus the equatorial atmosphere will have a motion with the earth of 1000 miles an hour, and the atmosphere at 60° will have a motion of 500 miles an hour, from west to east. But if the equatorial air, with its high velocity, is carried away in the upper-current to a place with a lower velocity, the air will still persevere in its equatorial speed, and will consequently outrun the speed of the place upon which it has come, and be felt as a strong wind in the direction of the rotation. If equatorial air were suddenly transplanted to 30° latitude, for example, it would be moving from west to east at the rate of 1000 miles an hour, over ground whose movement would be only 860 miles an hour; or the air would outrun the ground, or sweep over it at 140 miles an hour. This would have the effect of a westerly breeze of this degree of rapidity, and as such it would be felt by the inhabitants.

A similar explanation serves to shew that the under-currents from the poles to the equator will not be due north and south, but will have, in addition, a direction towards the west. Air from latitude 30° going upon the equator with an eastward velocity of 860 miles an hour, will move 140 miles an hour slower than the equatorial surface, or it will lag so much behind; and the effect will be felt as an easterly wind sweeping over the surface at this rate.

According to this simple theory, the prevailing winds ought everywhere on the earth's surface to be easterly: in the northern hemisphere, they should blow from the north-east; in the southern hemisphere, from the south-east. And within the tropics, and to some distance beyond them, this is in fact the case. The great polar currents are there known by the name of the *trade-winds*, because they are so constant that they can be calculated on by navigators. The trade-winds begin to be felt at about 30° of latitude on each side of the equator. Ships entering upon this belt begin to feel a steady easterly breeze, which continues, although with some variation, to within 2° of the equator. The two currents from north and south meet about the equator, and completely neutralise each other; and their meeting forms a belt varying from 150 to 550 miles in width, called the *region of calms and variables*. There is no steady wind in this region; its atmosphere is generally calm, having at certain seasons light southerly winds, interrupted by fearful storms and tornadoes.

Beyond the region of the trade-winds, the prevailing currents are in the opposite direction—in the northern hemisphere, for instance, from the south-west. To account for this, we must suppose that the two great currents change places, and that about the latitude of 30° the equatorial current descends to the surface of the earth. The annexed figure represents the way in which Lieutenant Maury conceives the air to circulate round the globe. 'Setting off from the north polar regions, a particle of air, for some reason which does not appear to have been very satisfactorily explained by philosophers, instead of travelling on the surface all the way from the pole to the equator, travels in the upper regions of the

atmosphere until it gets near the parallel of 30°. Here it meets, also in the clouds, the hypothetical particle that is coming from the south, and going north to take its place. About this parallel of 30° north, then, these two particles press against each other with the whole amount of their motive power, and produce a calm and

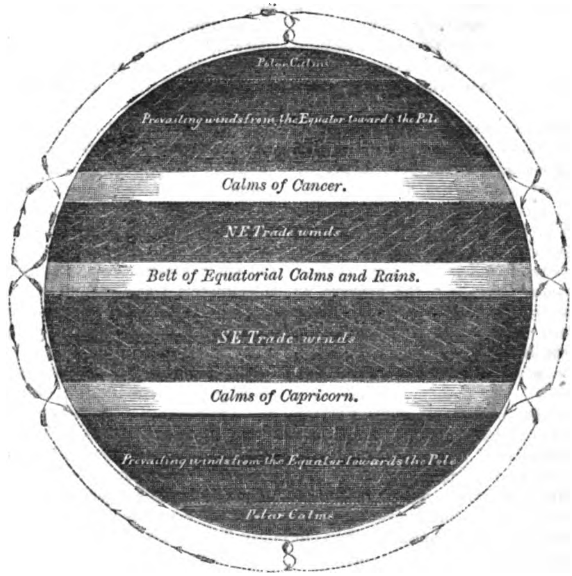


Diagram of the Winds.

an accumulation of atmosphere: this accumulation is sufficient to balance the pressure of the two winds from the north and south. From under this bank of calms, which seamen call the "horse-latitudes" [Calms of Cancer, in the diagram], two surface-currents of wind are ejected—one toward the equator, as the north-east trades, the other toward the pole, as the south-west passage-winds.'

The region of the south-east trade-winds is much larger than that of the north-east, the belt between them lying generally not at the equator, but several degrees north of it. The entire belt of the trades shifts in some degree northwards in summer, and southwards in winter, following the course of the sun.

Direct proofs have been furnished that in the regions of the trade-winds there are upper return-currents flowing in the contrary direction. The ashes of the volcano of St Vincent, on one occasion, were carried from west to east, to the astonishment of the inhabitants of Barbadoes, who were experiencing at the time the easterly wind. More striking still is the evidence furnished by the showers of dust, of a brick-red colour, that often fall on ships about the Cape de Verd Islands and in the Mediterranean. It was supposed to be brought from the parched deserts of Africa; but Ehrenberg, with his microscope, has shewn it to consist of infusoria and other organisms, belonging not to Africa but to South America. It would appear to be raised from the parched plains by the tornadoes of the equinoxes, and wafted by the upper-current across the Atlantic.

The great polar and equatorial currents are modified by another class of currents, of a more local and limited character, arising from the distribution of sea and land, and the unequal susceptibility of these to the sun's heat. If the sun shine with the same directness and force on two tracts of surface, the one water, and the other solid ground, the ground will be most rapidly heated, and at the end of the day it will be found much warmer than the water. On the other hand, in the absence of the sun, the land cools fastest, and at the end of the night it will be found below the temperature of the adjoining water. This difference causes an inequality in the temperature of the columns of air lying upon the two surfaces. When the land is hottest, the air resting upon it will be hotter and more expanded upwards than the air over the sea; hence the cold air from the sea will rush in upon the hot in the lower regions, and the hot will fall in upon the cold above. Thus during the day, when the land is warmer than the sea, there will be a breeze from the sea to the land, and during the night a breeze from the land to the sea. These are called the *sea and land breezes.* They rise regularly on all the sea-coasts. In calm weather, or when not overborne by other winds, they may be always observed. The sea-breeze, or the current from the sea to the land, begins at about eight or nine in the morning: at first it is gentle, and extends only to a short distance; it gradually increases, both in force and in extent, till about three o'clock in the afternoon, when it begins to decrease, and gradually to give place to the land-wind, which rises soon after sunset, and attains its greatest force in the morning.

On coasts where a large tract of land joins a great expanse of sea, as on the coasts of America and the south of Asia, the sea and land breezes become very considerable. The easterly trade-winds are often reversed by them. But the most powerful effect of the sea and land winds is annual, or dependent on the seasons. The most remarkable example of this is furnished by what are called the *monsoons*—from the Malay word *moussin*, signifying seasons—experienced along the coasts of Africa, India, and China. When the sun is far north in midsummer, and shines with direct rays on the Asiatic peninsulas, the land in them is rendered very much hotter, both day and night, than the ocean, and a strong sea-wind sets in towards these coasts from the south-west—that is, in a direction opposite to the great current that causes the trade-winds. Hence an immense wide-spreading conflict arises, which begins about the month of April, or two months before the sun has reached his extreme north declination. The first beginning of the conflict in April causes furious rain, wind, and thunder-storms; but in the course of two or three weeks the sea-breeze completely overcomes and suspends the trade-wind, and continues steadily to prevail from April to October; this is called the *south-west monsoon;*

and it can be as much calculated on for navigation as the trade-winds in their most uninterrupted regions. The influence which sustains this wind becomes gradually weaker as the sun moves southward, and in October it becomes too weak to overcome the trade-wind, and the two meeting with equal force, cause a second violent tumult of rain and storms, till in a short time the trade-wind prevails; which then continues during the winter half-year, and forms what is called the *north-east monsoon*.

In the Atlantic, a similar action is perceived. In the summer-time, the land of North Africa is made so much hotter than the adjoining sea, that a brisk south-west or south-south-west wind blows between the equator and the southern limit of the northern trade, which is then at about 10° or 12° north latitude. In America, also, similar breezes are experienced.

The chief sources of evaporation are the seas, lakes, and rivers: from these the moisture rises and diffuses itself over the land; and in general it must happen that the air lying on the seas and lakes must be more highly charged with watery vapour than the air lying on the land. The interior of continents will therefore be much drier than the sea-coasts. Between the valleys of the Irtish and the Obi, Humboldt found, after the winds had blown for a long time from the south-west, from the interior of the continent, that with a temperature of 75°, the dew-point was at 24°, giving a dryness of about $\frac{1}{10}$ths of an inch.

Although there is three times as much sea as land, this is not more than enough to keep up a sufficient moisture for the habitable countries; for although some regions have rather more than is desirable, many large tracts of country remain desert and uninhabitable solely from the dryness of their air and the scarcity of rain. If there had been as much land-surface as water, a far less portion of the globe would be habitable than at present.

The evaporation is necessarily greatest in the equatorial regions, where the temperature is greatest, and decreases steadily towards the poles. For the same reason, the precipitation of vapour, or the rain, must be most abundant in the warmest climates, and in the neighbourhood of the tropical seas. On the Malabar coast of the East Indian peninsula, at 11½° from the equator, the fall of rain in a year amounts to 123 inches, or to a lake of water 10 feet deep. In latitude 60°, the fall is reduced to 17 inches. In Great Britain, the annual fall is from 20 to 40 inches.* The quantity of rain on high grounds is often greater than at the sea-level, especially on mountains that stand in the way of moist winds. At Geneva, the annual fall is about 31 inches; at the Great St Bernard, it is 60 inches. At some places among the mountains of Cumberland, upwards of 100 inches fall, while in the plains to the east of them the fall is not greater than from 20 to 24 inches. These mountains interrupt the highly charged winds from the Atlantic, and receive a considerable portion of their vapour, rendering the air drier over the inland counties than at the sea-coast. In general, when a mountain-chain crosses the course of an ocean-wind, the weather-side is wet and the lee-side is dry. The trade-winds of the Atlantic sweeping over the continent of South America become cooled as they ascend towards the Andes, and, depositing their vapour, feed the mighty streams of the Amazon and Orinoco. On the west side of the wall of the Andes, in Peru, rain is almost unknown.

The greatest fall of rain on record is perhaps that observed by Mr Yule at Churra, north-east of Calcutta, among the Khasian Mountains. In the single month of August there fell 264 inches, of which 150 inches fell in the space of five consecutive days. Another observer at the same station measured 500 inches in the space of seven months. The cause of this unusual rain-fall is attributed to the abruptness of the Khasian Mountains, which face the Bay of Bengal, and intercept its moist winds.

Rain does not often fall in the constant trade-winds, owing chiefly to the steadiness of temperature. These constitute the great evaporating regions. But when the equatorial air, with its high temperature and high charge of vapour, goes some way into the cold latitudes, it is reduced in temperature, and can no longer contain its entire load of moisture, and rainy precipitations must ensue. Thus a constant distillation is going on from the tropical seas towards the regions without the tropics on each side. Hence, as a general rule, south winds with us are moist and rainy, and north winds are dry.

The daily and yearly courses of the sun cause daily and yearly fluctuations of the temperature, moisture, and pressure of the atmosphere; or in the thermometer, hygrometer, and barometer, which measure these fluctuations.

With regard to *temperature*, the *daily* fluctuation follows the career of the sun. It is lowest, or at a *minimum*, a little before sunrise, and it increases gradually from this time till two o'clock in the afternoon, when it is generally at its highest or a *maximum*. Although the sun is most powerful at noon, yet his effect in heating the earth does not attain its highest amount till about two hours after.

In the *annual* fluctuations of temperature, we find a similar course of rise and fall: there is an increase to a maximum in summer, and a decrease towards a minimum in winter. The intensity of the sun's rays is greatest in June, but the greatest heat occurs in July, or about a month after the longest day. In Paris, the highest temperature has been observed to happen on the 15th of July, and the least on the 14th of January. The days whose temperature is the mean or average of the whole year are about the 22d of April and the 20th of October.

The fluctuations of *vapour* follow the changes of temperature. As the temperature rises, evaporation increases, and the amount held in the air becomes greater. On the other hand, the diminution of the temperature leads to precipitations, and lessens the amount of the steam atmosphere. As the sun ascends in the heavens each day, the evaporation is promoted, and the absolute quantity in the air is increased; but this additional portion being very small in proportion to the whole increase of temperature, the actual dryness of the air is also increased until the maximum of heat has been attained. With the decline of the day the dryness diminishes, without a diminution of the actual amount of vapour, until the air cools down to the dew-point, when precipitation must begin. The dew-point temperature is every night sunk at least as low as the least temperature of the night.

The dryness of a day depends on the difference between the highest temperature of the day, and the least temperature of the night before; thus, if the maximum day-temperature were 60°, and the minimum of the previous night 40°, the dryness would be very considerable. But if the least temperature of a given night, and the greatest temperature of the next day, are very nearly equal, the air will be almost saturated with moisture the whole day. Thus dryness depends on cold nights preceding warm days. This rule, which connects the lowest temperature at night with the dew-point of the following day, may be violated by such accidental causes as the flowing in of warm, cold, or moist air, to change the character of the place. In

* The quantity of rain which falls at any station during a given time is ascertained by means of the *rain-gauge*—an instrument constructed in various ways. One of the simplest forms consists of a cylindrical copper vessel furnished with a float: the rain falling into the vessel raises the float, the stem of which is so graduated that an increase in depth, to the extent of one-hundredth of an inch, can be ascertained.

spite, however, of such casualties as these, the rule is generally true, and is very important in its applications, to inform us of the state of the air in respect of moisture, by means of the thermometer alone. If we take the lowest temperature of a night, and the average or mean temperature of the next day, the difference of the vapour sustainable at each will give the average dryness of that day. Thus if the minimum at night were 35°, and the average of the day 42°, then

Vapour at 42°, ...	·283 inch.
〃 35, ...	·222 〃
Dryness, or capacity for additional vapour,	·061 〃

Again, if the average temperature were 60°, and the lowest temperature 45°:

Vapour at 60°, ...	·523 inch.
〃 45, ...	·315 〃
Dryness, ...	·208 〃

In this last case the dryness is more than three times as great as in the other. And to prevent mistakes, it must be remembered that a difference of a certain number of degrees will cause a much greater dryness at a high temperature than at a low. Thus let us compare the extreme dryness of a winter and a summer day, on the supposition that in both cases the greatest range of the thermometer is 20°. Let the lowest temperature of the summer-day be 50°, for example, and the highest 70°:

Vapour that could be contained at 70°, .	·727 inch.
〃 〃 〃 50, . . .	·373 〃
Difference, or extreme dryness of the day,	·354 〃

Again, let the lowest temperature of the winter-day be 30°, and the highest 50°:

Vapour that could be sustained at 50°, .	·373 inch.
〃 〃 〃 30, . . .	·192 〃
Difference, or extreme dryness of the day,	·181 〃

Thus the dryness of the winter-day is only half that of the summer-day, although they have both the same range of 20°. And if we consider that a range of 20° is very often attained in summer, and very rare in winter, in a country like ours, we can judge what an immense difference there must be between the two seasons in point of dryness.

With regard to the fluctuations of *atmospheric pressure*, as shewn by the rise and fall of the barometer, it is found that between the tropics these fluctuations are very small, not extending to much above a quarter of an inch; but beyond the tropics they are very great, and the barometer has a range of three inches. The abundant aqueous precipitations which take place on each side of the tropics are the cause of these extensive fluctuations.

The barometer has in all places a regular daily fluctuation. From mid-day it falls until between three and five in the afternoon; it then rises again till between nine and eleven in the evening. It falls again to a second minimum about four in the morning, and rises to a second maximum about ten in the morning. The hours are not exactly the same for all countries, and the extent of variation is also different in different places, but the rise and fall twice in the twenty-four hours is a universal occurrence. The extent of the fluctuation diminishes as the latitude increases, according to a regular law. At Edinburgh, it is, on the average of the whole year, about $\frac{1}{100}$th of an inch; near the equator it is about ten times as great. There can be no doubt that these variations are connected with the daily variations of temperature and vapour arising from the course of the sun, but the exact way in which they are produced is not very clearly understood.

As we ascend in the air above the sea-level, or descend into the earth beneath it, we find a change of temperature. In ascending, the air becomes colder, at the rate of one degree of the thermometer to about 352 feet of ascent; the decrease of temperature being somewhat greater in high than in low latitudes, and not so much at great heights as near the earth's surface. The causes of this have been already explained. At a certain height over every place, water will freeze, and if a mountain rise to this height, it will be covered with snow. The height over any place where water must be frozen at all seasons is called the *snow-line*, the altitude of which is greatest at the equator, and diminishes as the latitude increases. At a certain high polar latitude it reaches the mean sea-level; that is to say, the ground at that level is eternally clad with snow.*

When we descend into the depths of the earth, by digging wells or mines, we find also a variation of the temperature. The influence of the sun is extinct about 100 feet below the surface. The difference between the day and night temperatures disappears at the depth of four feet; and the influence of summer and winter vanishes at about sixty or seventy feet, at which depth the temperature always stands about the average temperature of the climate; hence the temperature of spring-water proceeding from this stratum may be taken as the mean temperature of the place. At depths less than sixty feet, the ground is somewhat warmer in summer than in winter, but at greater depths the temperature is always the same. This depth, where the influence of season ceases to be felt, is called the *invariable stratum*. Beneath it the temperature increases gradually as we descend, shewing that the earth has a warmth of its own independent of the sun, or what is called its *central heat*.

According to some observations upon the increase of the central heat, it appears that for every fifty-nine feet of descent, the temperature rises one degree—others make the increase more rapid—so that if the temperature of the invariable stratum, or mean temperature of the place, were 52°, a depth of 10,000 feet would give the temperature of boiling-water, which would shew how far down the water lies which comes up in boiling-springs; at 60,000 feet, lead would be melted; and at twenty miles, cast iron would be liquid. We have no means of knowing if the heat increases steadily in this manner to the centre; but it is highly improbable that it should do so. We see, however, that volcanoes can be fed with burning matter, if their craters are connected with a stratum sufficiently deep to have the required temperature.

LAWS OF WEATHER.

Characteristics of Winds—Whirlwinds—Hurricanes—Rains—Storms.

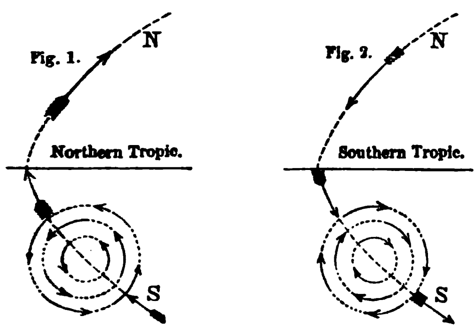
By the laws of weather are understood the fixed relations that have been discovered between the various circumstances of temperature, vapour, pressure, wind, rain, &c. Where such laws, rules, or fixed relations have been ascertained, we can infer one of the things from the presence of its invariable accompaniment, and can thereby often predict heat or cold, storm or calm, rain or dryness, before they actually happen.

We shall consider, first, the various kinds of *winds*, and their laws of connection with temperature, vapour, and pressure. We have already seen the nature of the great equatorial and polar currents, which take the lead of all other winds. The current towards the equator, by coming from a colder to a warmer region, is apt to be

* The *snow-line* is found at various heights, according to latitude, proximity to the sea, and other causes, which affect the general climate of the region. In the Himalaya and Andes, it is found at an elevation of about 17,000 feet; in the Swiss Alps, at 8500 feet; and in the Scandinavian range, at 3500 feet. Generally, in those countries which are near the equator, the snow-line is found about 16,000 feet, or three miles above the sea-level: about the 45th parallel in either hemisphere, it occurs at an elevation of 9000 feet; under 60° of latitude, at 5000 feet or thereby; under 70° latitude, at 1000 feet; and under 80°, the snow-line comes down to the mean sea-level; for countries which are 10° distant from the poles are covered with snow all the year round.

comparatively cool and dry; while the opposite current must be very moist and warm. This great characteristic difference between these two currents is found all over the earth. It is a general rule in our hemisphere, that north-east winds are cold and dry, and south-west winds warm and moist. There are exceptions to this principle produced by the irregularities of land and sea climates, but it is true in the great majority of instances.*

Hurricanes are huge eddies or whirls in the atmosphere, supposed to be produced by the meeting of the upper and under currents in the course of the descent of the upper to the earth, or by a sudden deposition of moisture. They are whirlwinds on a great scale, having two motions, a progressive and a rotary, both following certain fixed laws. Fig. 1, in the accompanying diagram,



indicates the motions of a rotary storm in the northern hemisphere. Originating within the tropics, it travels in a curve, first north-west, and then north-east; while the direction of the whirl is *against the hands of a watch*. In the southern hemisphere, the progressive motion is from the intertropical regions (fig. 2), first south-west, and then south-east, and the rotary motion is *with the hands of a watch*. By taking advantage of this 'law of storms,' a ship may sail out of a hurricane.

A *water-spout* or land-spout seems to be a rotary storm or tornado of narrow dimensions, by which a cloud is thrown into a rapid whirl. It is generally accompanied by violent rain, hail, and lightning; but whether the electricity manifested is cause or effect, is a disputed point. The cloud generally assumes the form of an inverted cone; and when it is over water, a whirling column of spray rises to meet it.

Even in the region of *variable* winds, some degree of regularity is observable. The south-west and the north-east prevail alternately during the greater part of the year, and by their conflict Professor Dove of Berlin accounts for the intermediate winds. He shews that as these variable winds veer round the compass, they usually follow a certain course—namely, from east to west by south in the northern hemisphere, and from east to west by north in the southern hemisphere.

* Every gradation exists in the speed of winds, from the gentlest zephyr to the most violent hurricane. They have been classed by Smeaton, according to their rapidity and force, as follows:—

Velocity. Miles per Hour.	Force on One Square Foot, in Pounds Avoirdupois.	Appellation.
1	·005	Hardly perceptible.
4	·079	Gentle breeze.
5	·123	
10	·492	Pleasant brisk gale.
15	1·107	
20	1·968	Very brisk.
25	3·075	
30	4·429	High wind.
35	6·027	
40	7·873	Very high.
50	12·300	Storm.
60	17·715	Great storm.
80	31·490	Hurricane.
100	49·200	Violent hurricane.

The winds between north and east have generally the smallest amount of *vapour*. At the same time, from their being the coldest, their actual dryness, or the difference between their temperature and the dew-point, is often less than in other winds. The south winds have both the greatest amount of vapour and the greatest vacancy or dryness.

The *pressure* of the air, or the height of the barometer, varies during the different winds. The barometer generally falls during south-east and south winds; passes from falling to rising during south-west; rises with west, north-west, and north winds; and has its greatest rise with north-east winds. The rise of the barometer with a north-east wind is very commonly remarked. The mercurial column is usually at its lowest between south and south-west.

It is a general law, or invariable connection, between the amount of vapour and the pressure of the atmosphere or the height of the barometer, that they change in opposite directions. In summer, when the quantity of vapour is greatest, the pressure of the air is least; and in the winter-time, the vapour being least, the weight of the air is greatest. Even in the daily fluctuations of these two quantities, this opposition is perceivable.

The fall of *rain* will depend upon a variety of circumstances. On the sea-coasts, and in places visited by moist winds, in which the approach to saturation is highest, the falls of rain will be most frequent, and there will be a greater degree of cloudiness prevalent in the sky. In the interior of continents, where the dryness is great, or the dew-point generally much lower than the temperature, rain will be less frequent, and the sky will be more transparent. In England and the west of France, there are, on an average, 152 rainy days in the year; in the interior of France, 147; in the plains of Germany, 141; and in the interior of Siberia, only 60. In many parts of Africa, rain never falls; in Upper Egypt, it is very rarely known. On the west coast of Britain, it rains much more frequently than on the east, the reason being, that the westerly winds—from the Atlantic—are moist winds, and give forth the greatest quantity of moisture on the land upon which they first strike.

When the visible vapour from a hot spring, a boiling caldron, or a steam-engine, extends in a long train, it is a sign that the air is nearly saturated with moisture, and that rain may be expected. If the appearance occurs about two or three o'clock in the afternoon, it may be reckoned as certain that there will be rain, mists, or dews at nightfall.

In extreme frosts, there can never be great falls of snow, the whole of the moisture contained in the air being too small to afford a copious precipitation.

In *predicting* weather by consulting instruments, it would be necessary to use the hygrometer along with the barometer and the thermometer. There are many exceptions to the common notion, that a high barometer indicates fine weather, and a low barometer the contrary. But even the barometer alone would be more certain if the following points were attended to—namely, in the *first* place, the actual height of the mercury; *secondly*, whether it is rising or falling; *thirdly*, the rate of rise and fall; and *fourthly*, whether the rise or fall has been of long duration. A slow rise continued for some days gives promise of settled weather; a steady and long-continued fall indicates that a tract of unsettled and stormy weather may be expected. There are also certain hours of the day which ought to be preferred for making the observations. For three observations daily, the proper times are—nine A.M. (a maximum height), twelve noon (a mean height), and three P.M. (a minimum height); when convenient, a fourth should be added—namely, three A.M. For two observations daily, nine o'clock morning and evening are the best hours; for one daily, noon is preferable.

These are the hours best suited for taking observations which are to be kept on record, and also for consulting the instrument to prognosticate the weather. If the column rise between nine A.M. and three P.M., it indicates fine weather; if it fall from three P.M. to nine P.M., rain may be expected. These rises and falls are contrary to its regular daily course, and therefore indicate considerable changes in the pressure of the air.

A sudden and great fall of the barometer is the sure forerunner of a violent storm. It shews that a great displacement or vacancy has occurred in the air over the place, and that a great inward rush will occur to make it good. A sudden rise would indicate an accumulation of air, which would cause an outflow in all directions, and would be also felt as a storm somewhere. A slow rise or fall shews that the influence comes from a great distance, or is owing to a permanent cause; hence, whatever the consequence may be, it will probably last for some time. A high barometer is a security against vehement influxes of air on any side, and therefore against the carrying in of moisture; hence it prognosticates dry and clear weather.

The hygrometer is very valuable in predicting weather; for as the quantity of vapour in the air increases or declines, so does the probability of the occurrence of rain. The hours already stated for the observation of the barometer are also well adapted for the hygrometer, with the view either of keeping a register or of ascertaining the course of the weather. The average pressure of the vapour for the day should be calculated by taking a mean between the dew-point at three P.M. and the lowest temperature of the sheltered thermometer at night.

By examining the barometer along with the hygrometer the prediction of weather is made much more certain. A fall of the barometer, accompanied with a rise in the dew-point, is an infallible indication that the entire mass of the air is becoming imbued with moisture; and a copious fall of rain may be looked for. If the fall of the barometer take place when the dew-point is low, we may conclude that the expansion that has occasioned the fall has taken place at a distant point, and wind without rain will be the result. When the temperature of the air sinks to the dew-point, with a high barometer, the effect is probably transitory, and produced by a local depression of temperature.

The Moon and the Weather.—The belief is almost universal, that the weather is influenced by the phases of the moon. A *change* of the weather, either from foul to fair, or from fair to foul, may be specially looked for, it is thought, at the times of new and full moon, or even at the quarters, though these last are not considered so influential. This belief is found to be altogether without foundation. Accurate observations, made with the express purpose, and extended over long periods, shew that there is not the slightest correspondence between the two sets of phenomena.

CLIMATES.

Isothermal Lines—Zones of Distinct Vegetation—Insular and Continental Climatology—Climate of London.

The climate of a place depends on its distance from the equator, its height above the sea-level, its position in reference to oceans, seas, and continents, the form of its surface, and the character of its soil. The points to be stated in reference to climate are, the mean temperature, the extreme winter and summer temperatures, the range of temperature daily, and from day to day, the humidity, the total fall of rain, the frequency of the falls, the relation of the amount fallen to the ordinary amount of vapour in the air, the prevailing winds, and the degree of variability of the weather. In general, the southern hemisphere of the globe is colder than the northern.

Humboldt divided each of the two hemispheres into seven belts or zones of climate, by supposing lines to be drawn round and round the globe, somewhat like parallels of latitude, each line running through all places whose *mean temperature* is the same. These are called *isothermal lines;* and as vegetation depends on warmth, they serve to distinguish the zones of distinct vegetation.*

Next the equator is the *equatorial* zone, or the *spice* climate, bounded by the line passing through places of 78° of mean temperature, which line lies nearly at 20° of latitude. The finest spices and the hardest woods thrive in this region. The second zone is the *tropical* climate, and is bounded by the line of 68°, and includes the climate of the sugar-cane and coffee-tree. In North America it is 31° from the equator; in Europe, the Mediterranean, Asia Minor, and Syria, it extends to 37° latitude; in Persia, to 31°. Here all the species of the palm-tree are in great perfection; the orange, lemon, and citron are of the most delicious flavour; and Indian corn, rice, cotton, tobacco, indigo, dye-woods, and drugs, are also among the productions. The third or *warm* climate extends to the line of 59°, the boundary of the olive and fig. In America it extends to latitude 36°; in Europe, to latitude 44°; in the west of Asia it extends to 40°; and in the central high regions, to 35°. This zone yields the olive, fig, almonds, peaches, apricots, the mulberry for feeding the silk-worm, the vine, yielding the choicest wines, the cork-tree, drugs, barilla, dried fruits, &c. The fourth or *temperate* climate coincides with the line of 50°, mean temperature, and is the limit of the wine-grape. In the middle of Europe it extends to latitude 50°, on the coast, to 52°; in England and Ireland, to 53°; in America, on the east coast, to 43°, and on the western coast, to about 50°; and in Asia it is as low as 40° latitude. It is the climate of grain, of the oak, beech, maple, and other valuable timbers; also of plums, cherries, apples, and pears. The fifth or *cold* climate terminates at the line of 41° of temperature, which is the northern boundary of the oak and of wheat: it yields the pine and fir, oats, barley, rye, apples, pears, nuts, gooseberries, and strawberries. The sixth or *frozen* climate is bounded by the line of 32°, or freezing; it extends in Lapland to 66° latitude; and to Table Bay, Labrador, at 54°. It contains little vegetation; its chief productions are animal products, such as whalebone, train-oil, and furs. Beyond this is the seventh or *polar* climate, which extends to the region of perpetual snows, where all vegetation ends: it yields only a few stunted shrubs, lichens, and mosses.

In ascending a mountain, we find a gradual diminution of temperature, analogous to the transition from the equator to the poles; and the same succession in the classes of vegetable life. On the sides of Tenerife, Humboldt observed the vegetation of nearly all the climates of the world. In temperate latitudes, though the variety of vegetation be less, similar phenomena present themselves. 'We may begin the ascent of the Alps, for instance, in the midst of warm vineyards, and pass through a succession of oaks, sweet chestnuts, and beeches, till we gain the elevation of the more hardy pines and stunted birches, and tread on pastures fringed by borders of perpetual snow. At the elevation of 1950 feet, the vine disappears; and at 1000 feet higher, the sweet chestnuts cease to thrive; 1000 feet further, and the oak is unable to maintain itself; the birch ceases to grow at an elevation of 4680, and the spruce-fir at the height of 5900 feet, beyond which no tree appears. The rhododendron ferrugineum then covers immense tracts to the height of 7800 feet, and the herbaceous willow creeps 200 or 300 feet higher, accompanied by a few saxifrages, gentians, and grasses, while lichens and mosses struggle up to the imperishable barrier of eternal snow.'

* Places which have the same mean annual temperature vary considerably in their mean summer and winter temperature; hence *isochimenal* lines, or lines of equal winter temperature, and *isotheral* lines, or those which shew equal summer over points upon different isothermal curves.

But the mean temperature is not the only circumstance which determines the vegetation of a place. The boundary of some plants depends on the lowest temperature of winter; and the advantageous cultivation of most plants is ruled by the greatest summer heat, as in the case of the vine, the olive, and maize or Indian corn. Barley is said to ripen wherever the mean temperature of ninety consecutive days rises to 48°. It is highly improbable, and in opposition to all evidence, that the mean temperature of any place on the globe has been changed within the periods known to history.

Between the tropics, the year is divided into the wet and the dry seasons. The wet or rainy season is the summer, or the time of the sun's most direct action; in *north* latitudes it extends from April to October. The division of the year into four seasons is known only in the temperate zones, or between 40° and 60° of latitude.

The western coasts of continents beyond the tropics have a much higher temperature than the eastern coasts, arising, partly at least, from the heat evolved in the condensation of vapour from the prevailing westerly winds.

Next to the distinction of climates into hot and cold, is the difference between *insular* and *continental* situations. Insular climates are kept temperate by the sea; they do not experience the extremes of heat and cold that are felt in the interior of continents. Thus if we compare Nova Zembla with Fort Franklin, which have nearly the same mean temperature, we shall find in the extremes of each the indication of its position:

	Nova Zembla.	Fort Franklin.
Mean temperature, . . .	16°·	17°·6
Mean of three summer months,	36 ·5	50 ·4
" " winter " ,	—3 ·	—17 ·8
Extreme heat, ...	49 ·	80 ·
" cold, ...	—53	—58
Range of heat and cold, . .	102	138

Both the vegetation and the feelings of human beings will be very different in these climates. The high summer heat of the one will favour the growth of many plants, and give a tone of warmth and cheerfulness; the miserable cold mediocrity and monotony of the other will be barren and disheartening.

The British Islands are situated so as to experience almost all the circumstances that can render a climate irregular. Standing nearly in the centre of the temperate zone, where the range of temperature is very great, they are subject on one side to the impressions made on the atmosphere by the greatest continent of the world, and on the other side to the influences of the Atlantic Ocean. The Gulf Stream (see Physical Geography) is believed to have considerable influence in mitigating the rigour of winter in the British Islands and the west of Europe generally.

On the average of ten years, the westerly winds are to the easterly, in Great Britain, as 225 to 140; and the northerly to the southerly as 192 to 173. Of east winds, the northerly exceed the southerly in the proportion of about 74 to 54; thus the south-east, which is the most irregular point of all, has but a small proportion. The south-west are to the south-east as 104 to 54.

Within the boundaries of Great Britain there is a considerable variety of climate. The character of each place can be ascertained only by a long series of well-conducted instrumental observations; and few places have as yet received this degree of attention. Hitherto London has been the place most carefully observed.

The mean pressure of the air at London, as deduced from twenty years' observations by Mr Howard, is 29·8655, or very nearly $29\frac{9}{10}$ inches. The mean temperature derived from the daily extremes is $49\frac{1}{2}$°. The mean dew-point is $44\frac{1}{2}$°, giving a mean dryness of 5°, which for these numbers corresponds to a vacancy or dryness of ·058, or nearly $\frac{1}{17}$th of an inch. The average quantity of rain is 22·199 inches annually, and the amount of evaporation is calculated at 23·974 inches—that is, considerably greater than the entire amount received by precipitation.

The range of the barometer is from 30·82 inches to 28·12 inches; the maximum temperature of the air is 90°; the minimum 11°; the range of the dew-point is from 70° to 11°. The highest temperature of the sun's rays is 154°, and the lowest temperature on the surface of the earth 5°. The greatest interval between the temperature and the dew-point is 29°.

ELECTRICITY OF THE ATMOSPHERE.

Thunder and Lightning—Aurora Borealis.

The electric phenomena of the atmosphere possess great interest, but are as yet imperfectly understood (see Electricity). The condensation of vapour is thought to be the most productive source of the electricity of the atmosphere. The excitement is much oftener positive than negative. The discharges of the excitement are well known under the terms *thunder* and *lightning*, and they generally accompany storms and hurricanes, but rather as effects than causes. According to Mr Crosse, a thunder-cloud consists of zones alternately positive and negative; and different strata of serene air are often in different relative electric states. Such a state of things makes the whole subject of atmospheric electricity exceedingly complicated.

The *aurora borealis*, one of the most beautiful of meteoric phenomena, is now ascertained to be connected with the *magnetism* of the earth. Faraday has shewn that magnetic forces can produce light; and the appearance of the aurora is always preceded by a disturbance of the earth's magnetism, as shewn by the vibrations of the magnetic needle. The polar light is a magnetic discharge—the termination of a magnetic storm—just as a flash of lightning indicates the restoration of the disturbed electrical equilibrium. The rays of the aurora appear to converge towards a point in the vault of the heavens corresponding to the inclination of the magnetic needle. The formation of fleecy, cirrus clouds is always more or less connected with the appearance of the aurora. These clouds may often be observed even by day arranged similarly to the rays of the polar light; and they are then found to disturb the course of the needle in a similar manner.

LUMINOUS METEORS.

Rainbows—Halos—Parhelia—Coronæ, &c.

The various luminous appearances of the heavens, apart from the ordinary phenomena of sun, moon, and star light, are usually treated of under Meteorology.

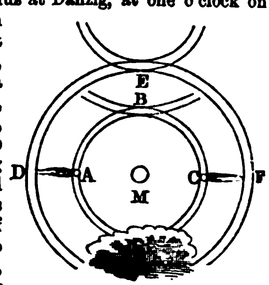
If there were no atmosphere, the heavens would be intensely black at all times, and the heavenly bodies would be brilliant lights set in the deepest shadow. The air, however, diffuses and reflects the sun's light, so that a portion of it is received from every part of the sky, causing a general illumination of the entire vault of heaven. This reflected light ought to be always of a whitish character, like the light of the sun itself made very much fainter. But we find that the sky, when clear, has a strong blue tinge, which deepens into black as we ascend to great heights. The blueness arises from the peculiar action of the atmosphere upon light. If any white beam pass through a great thickness of air, the red will be transmitted most readily, and the blue resisted and reflected; hence the reflected rays of the sun's light have a bluish tinge instead of being pure white. The reddish character of light transmitted very obliquely through a great thickness of atmosphere, is exemplified in the ruddy illumination of the sky and the clouds at sunset.

The *rainbow* is owing to a complicated reflection and decomposition of the rays of the sun in passing through drops of rain. It appears when the sun is unclouded, and rain is falling in the opposite quarter of the heavens.

The mode of its formation is more particularly explained under OPTICS.

Halos are coloured rings which surround the sun at considerable distances from his body. Two of them may be seen at once, the one about double the distance of the other; and sometimes a third, at twice the distance of the second, and about 90° or a quarter of a circle from the sun. The smaller circles are generally coloured, the red being innermost. They are supposed to rise from the action of the icy particles in the upper air upon the rays of light. These particles naturally aggregate into needles or prisms of three or six sides, and the refraction of the light through them would account for the colours of the rings, and for the distances at which they stand from the sun. *Parhelia*, or mock-suns, and *paraselenæ*, or mock-moons, are supposed to be owing to reflection from the same icy particles.

In the annexed figure, a representation is given of a lunar halo seen by Hevelius at Danzig, at one o'clock on the morning of the 30th March 1660. When first perceived, the moon, M, was surrounded by a complete whitish circle, ABC, 45° in diameter, while at A and C were mock-suns, displaying *various colours*, and shooting out at intervals very long streams of whitish light. At two o'clock, the larger circle, DEF, was seen reaching down to the horizon, having a diameter of 90°. The tops of both circles were *touched* by *coloured arches*, like inverted rainbows, the *red* tint being *next to the moon*. The arch B was part of a circle equal in size to DEF, while that at E was a portion of a circle of the same magnitude as ABC. Such is the general structure of halos: the identity existing in the magnitude and arrangement of their several parts, clearly shews that they must originate in certain fixed laws; but what those laws are has not yet been fully determined.



The true halos are to be distinguished from the *coronæ*, or *glories*, that surround the sun or moon when a thin cloud passes over them. These depend on a different optical principle. When fine powder of any kind is interposed between the eye and a luminous object, rings of colours are formed, whose size depends on the dimensions of the powder. Visible vapour will produce this effect; and it also arises from the fine dust always held in suspension in the air of a room. Such rings can be observed round a candle-flame at any time, if we stand at a proper distance from the light; and by the agitation of the dust, they may be made still more visible. By calculation, Dr Young has shewn that rings 8° in diameter are produced by particles of powder, or drops whose diameter is $\frac{1}{3181}$ of an inch.

IGNEOUS METEORS.

Shooting-stars—Fire-balls—Meteoric stones—Aërolites.

Shooting-stars are observed during serene nights. A luminous point like a star bursts into view, shoots a certain way through space, and then disappears. Its brilliancy fades before it is extinguished. Sometimes it leaves a luminous train behind it; in other cases it gives forth sparks. These meteors have been noticed to occur in great numbers at once; and the interest of such appearances has been very much increased by the fact of their being in some measure periodical. On several years they have been found to occur in the month of November; from which circumstance they are sometimes called November meteors. They also occur with some degree of frequency in August. Shooting-stars and *fire-balls* break out occasionally at every period of the year.

When a fire-ball bursts, the fragments fall to the earth, and are called *meteoric stones*, or *aërolites*, from the Greek words *aër*, atmosphere, and *lithos*, a stone. Many of these stones have been procured and examined, and found to be quite unlike any mineral of terrestrial origin; hence the most likely theory of their derivation is, that they are fragments flying through space, under the influence of the same forces which sustain the planetary motions, and that they sometimes come within the sphere of the earth's attraction, so as to be drawn down to its surface. There is every reason to believe that the planets, satellites, and comets are not the only bodies which move round the sun, and lie within the solar system—they are merely the large conspicuous masses; while millions of others may exist, too small to be descried on ordinary occasions, and making themselves known only by falling upon the earth. Their illuminated appearance is supposed to be owing to their taking fire when they come in contact with the oxygen of our atmosphere. They themselves have evidently no oxygen atmosphere of their own, but are not improbably surrounded by some inflammable gas, the combustion of which forms the luminous train that they leave in their track. To account for the periodicity of the November meteors, it is imagined that a great number of them may move in a continuous ring or common orbit round the sun, so situated that the earth, in its annual course, brushes, as it were, with the outskirts of its atmosphere this ring of planetary fragments once a year. Some of them pass into the atmosphere, and go out again, without falling to the earth; shewing that the earth can only deflect them a certain way, and is not able to draw them completely down to the surface.

One of the most familiar of luminous meteors is the *ignis fatuus*, or 'Will o' the wisp,' which appears at night on marshy grounds, places of sepulture, or wherever putrefaction and decomposition are going on. The appearance is that of a small flickering light, straggling in an irregular manner at the height of one or two feet from the ground, and sometimes standing for a few moments over a particular spot. When approached or pursued, the lights are agitated by the motion of the air, and seem to elude investigation. The cause of this species of meteor is supposed to be an evolution of phosphoretted hydrogen gas, which, properly speaking, does not burn as a flame, but is only faintly phosphorescent.

Until recently, meteorological observations had been mostly casual and without any uniform plan; hence the vagueness and uncertainty that hang over so much of the subject. But since 1840, the earth has been covered with a net-work of meteorological observatories, maintained by the several European governments—Russia and England taking the lead—in which observations of a variety of physical phenomena are made on a concerted plan, determined on by savans in congress. In consequence also of a maritime congress held at Brussels in 1853, chiefly at the instigation of Lieutenant Maury of the United States, the chief maritime nations are taking means to render every ship, whether man-of-war or merchantman, a floating observatory, by furnishing captains with instruments and instructions how to record what they see. Observations of a more local kind are also being actively prosecuted in various quarters, with a view to the interests of agriculture. A recent writer in the *North British Review* is of opinion that 'had Hipparchus and Ptolemy made hourly observations, and had they been made also by their contemporaries and successors in different parts of the world, we might now have been predicting the weather with as much certainty as we do the planetary motions.' Without being quite so sanguine, it is not unreasonable to anticipate that, with the agents and apparatus now at work in this field, the next half-century may see light and order arising out of many things that now seem nothing but chaos.

PHYSICAL GEOGRAPHY.

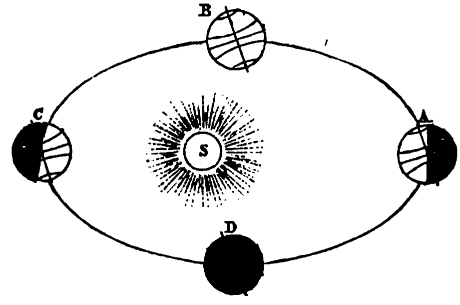
GEOGRAPHY—from *gé*, the earth, and *grapho*, I write—in its simple and literal signification, is that science which describes the superficial appearance and conditions of our globe. It naturally divides itself into two great branches—1. *Physical Geography*, which treats of the earth as a superficies composed of land and water; considers the position, extent, altitude, and general character of the former; and the position, extent, depth, currents, and other motions of the latter: in short, all that relates to the distribution of land and water, variations of surface, temperature and climate, and distribution of plants and animals as dependent thereon, are the legitimate objects of this species of geography. 2. *Political Geography*, which refers merely to the division of the earth's surface by man into territories, empires, kingdoms, and states, treats of their boundaries, the history of their occupation, their produce, commerce, population, laws, religion, and other topics which constitute the fundamental features of human polity. The latter of these branches will form the subject of several subsequent treatises; to an exposition of the former—dwelling more on principles than on mere descriptive details—we intend to devote the present number. Before doing so, however, it will be necessary to advert to the cosmical relations and constitution of our planet, as determined by astronomy, geology, chemistry, and meteorology.

GENERAL CONSTITUTION OF THE GLOBE.

Astronomy informs us that the earth we inhabit is one of a number of *planets* which revolve round the sun as a common centre, constituting what is usually denominated the SOLAR SYSTEM. These planets are situated at different distances from the central orb, and differ also in their magnitudes, their densities, and in their periods of revolution. They are nearly spherical in form, are opaque, have no light of their own, but merely reflect that of the sun; and all move from west to east in nearly circular orbits. Several of them serve in turn as centres for other bodies of revolution, which are known by the name of *satellites*—as the moon, for example, which is the satellite or attendant of the earth. Besides the planets and their satellites, there is a third and numerous class of bodies belonging to the solar system—namely, *comets*, which revolve round the sun in regular periods, but in orbits so elliptical, that in parts of their course they approach nearer to the great orb than any of the planets, and in others recede so far into the regions of space, as to be entirely beyond the reach of our most powerful telescopes. The *stars* belong to other systems of revolution, and have, so far as has yet been determined, no perceptible effect upon the conditions of our globe, though undoubtedly bearing, like everything in nature, a universal harmonious relationship.

The earth, as an individual planet, is situated at the distance of 95,173,000 miles from the sun; has a mean diameter of 7912 miles; performs a revolution round the sun in 365 days 5 hours 48 minutes and 49 seconds, which constitutes the space of time called a year; rotates on its own axis once in 24 hours—that is, in one day; and in these movements is attended by the moon, which is distant 237,000 miles, is 2160 miles in diameter, and which completes her synodic revolution in 29 days 12 hours and 44 minutes, or in one lunar month. We have spoken here of the *mean* diameter of the earth, because, upon accurate measurement, it has been found to be not a perfect sphere, but an *oblate spheroid*, whose greater diameter is 7925·648, and whose lesser is only 7899·170 miles. This gives a difference of 26·478 miles between the two diameters, or a flattening at each pole of about thirteen miles—a result that may be artificially illustrated by twirling with rapidity a ball of any yielding material, such as putty, round a spit thrust through it as an axis, when a bulging at the outer circumference will take place, causing the ball to lose its original spherical form. This bulging takes place through what is called the law of centrifugal force; and from what we know of this law, it is concluded that the earth was in a soft or yielding state at the time when it assumed its present form. Besides the bulk, revolutions, and configuration of our globe, science has also determined its *density* with considerable accuracy. By weighing the most prevalent rocks, it has been found that the solid crust composed of them is about two and a half times heavier than water; but from experiments made on the attraction of mountains of known bulk, compared with the attraction and bulk of the globe, and by other means, it has been inferred that the density of the whole mass is five or six times that of water: in other words, the earth, as at present constituted, is five or six times heavier than a globe of water of similar dimensions, and more than twice the weight of one composed of such rocky substances as those with which we are acquainted. In addition to what may be called its own proper material, the earth is surrounded by a gaseous envelope or atmosphere. This *atmosphere* or air is peculiar to, and inseparable from, our globe—it rotates with the solid mass upon its axis, and does not, as may at first be supposed, occupy the space in which the rest of the heavenly bodies revolve. Like all aëriform and liquid masses whose particles press upon each other equally in every direction, the portions or strata next the earth are more pressed upon than those in higher regions; and continuing this conception, a height must be arrived at where the air becomes so attenuated as to be inappreciable. Thus it has been determined that the atmosphere does not extend beyond forty-five miles from the mean level of the ocean.

From its planetary relations, as a part of the solar system, the earth derives its figure and motions, its light and heat, and consequently the changes of season, and the alternation of day and night; the phases of the moon, and the rising and falling of the tides; the vicissitudes of wind and weather, and all the varied results and phenomena that flow therefrom. Thus,



while its figure is preserved by the laws of centripetal and centrifugal force, its motions are determined and influenced by the attraction and gravitation of the sun

and other planets. From its situation with respect to the sun, it necessarily follows that only one-half of its surface can be exposed at a time to the light and heat diffused from that orb, thereby causing day in the one part, and night in the other. The *seasons*, again, are caused chiefly by the fact, that in performing its path round the sun, the earth preserves its axis in a slanting or oblique position, to the extent of 23° 28′ from the perpendicular. A glance at the figure shews how this obliquity makes the several parts of the earth's surface receive different amounts of light and heat in different parts of its orbit; as has been more particularly explained in ASTRONOMY. In like manner, did our limits allow, might be explained the phases and influences of the moon, and the fluctuations of heat and cold, with their myriad consequences to animal and vegetable existence. So indissolubly connected is the whole scheme of creation, that not a shower that falls, not a particle of sand that crumbles away from its parent rock, or a spikelet of grass that turns sunward, but may be traced to the one great law which originally set the sun and its attendant orbs in motion.

The solar system, however, vast as it seems, is but a unit in space, which is peopled with other systems and orbs circling and encircling beyond the bounds of human conception. What we term *fixed stars* are but suns and centres of revolution; and the solar system, as a whole, may revolve in space round some vast centre, just as its individual planets have their motions round the sun. From such a revolution may arise cycles of heat or cold, life or death, exuberance of certain living forms, and annihilation of others—cycles which meet with a faint analogy in the recurrences of our summers and winters. We know nothing of the constitution of what we call space, or of the ethereal essences which pervade it; and it is not unlikely that as the solar system passes through successive regions, causes may operate on a scale sufficiently vast to impress new conditions upon the whole of the planets which constitute that system. But, whether our earth be or be not affected by causes so remote and universal, we know for certain that its history, from the beginning of time, has been one of incessant mutation and progress.

The materials of which the earth is composed present a history not less curious than that of its planetary relations. Superficially speaking, the globe consists of land and water; the water occupying the extreme depressions of the land, and this land composed of solid or rocky materials. That the same kind of rocks which appear at the surface do not constitute the interior or central portions, we have evidence from the mean density of the earth; for were the law of gravitation to exert itself uniformly towards the centre, the lightest substance at the surface would be so compressed at the depth of a few hundred miles, as to give to the whole a greater density than astronomical calculations will allow. The interior, therefore, must consist of very different material from the exterior, and this has led geologists to speak of the earth's *crust*, whose composition we know, in contradistinction to the central portion, concerning which we can only form conjectures. This crust, or external shell of solid matter, consists of rocks, differing not only in their appearance and arrangement, but in their mineral and chemical characters; some being compact and crystalline, as marble, others soft and dull, as chalk; some lying in layers or strata, others occurring in huge irregular masses; while, mineralogically and chemically speaking, we have such rocks as granite, quartz, slate, lime, coal, rock-salt, chalk, and clay. But the crust so composed, compact and solid as it may seem, is far from being permanent and stable; in other words, the dry land which now appears, with all its irregularities of hill and valley, plain and ravine, lake and river, is not the dry land which existed many thousands of years ago. Strictly speaking, indeed, the aspect of the globe is ever changing. Here the sea encroaches on the land, there the débris borne down by rivers silts up bays and estuaries; here earthquakes sink, and volcanoes elevate the surface; lakes are dried up, and rivers change their course; and, greater than all of these, vast regions gradually subside, and are covered by the ocean, while others as gradually emerge from the waters, and become dry land. All these changes, past and present, form the subject of geological consideration.

Geology, in its aim to decipher the physical history of our globe, has determined that all the known rocks may be ranked under two great sections—the *stratified* and the *unstratified*. The former appear in layers or beds, and have evidently been deposited in water, hence said to be *aqueous* or *sedimentary;* the latter appear in vast irregular masses, generally disrupting the stratified

rocks, and have all the appearance of having been formed like the lavas of the present day; hence they are called *igneous* or *volcanic*. Of the sedimentary rocks, sandstone, limestone, slate, and coal may be taken as illustrative examples; of the igneous, granite, basalt, greenstone, and lava are the most familiar. As at present, so in all time past, the surface of the earth has been subjected to atmospheric, aqueous, and other influences, the effects of which are to wear down the exposed material; and this, borne away by floods and rivers, is deposited in the ocean, where, consolidated by pressure, heat, and chemical agency, it forms new strata of rocks, which in time are brought to the surface by volcanic and other elevatory forces. Thus, then, one set of agencies degrade, and another reconstruct and elevate; and in proportion as either of these preponderate, so will any portion of the earth be low and level, or high and precipitous. Such, then, is the origin of the stratified and unstratified rocks—the one but the reconsolidated matter of pre-existing rocks, which have been worn and battered down by rains, frosts, waves, and rivers; the other the cooled and hardened material sent forth from the interior of the earth by volcanic agency. But while rivers and floods bear down mud, sand, and the like, they also carry such vegetable and animal remains as lie in their course; and in this manner plants and animals are entombed in the newly formed layers or strata. As at present, so in former eras, such remains have been enclosed in the stratified rocks, where, subjected to certain chemical agencies, they have become petrified, and are thus preserved as records of the former Flora and Fauna which peopled the globe. Geologists have, accordingly, found that the earth has not always been occupied by the same kinds of plants and animals that now exist; but that different eras in its onward history have had very different Flora and Fauna, and that at present not one perhaps of its former genera is in existence.

Aided by the mineral composition of the rocks themselves, and by these fossil organisms which are found in them, geologists have arranged the strata composing the accessible crust into *formations;* that is, into series of strata which seem to have been deposited under the same terrestrial conditions. Thus the *primary* formation includes the hard crystalline and slaty strata, as gneiss, mica-schist, clay-slate, &c., in none of which organic remains have yet been found, and whose material has evidently been derived from the granitic rocks on which they rest as a basis or foundation. Next in succession above the primary are the *transition* rocks, so called from their containing remains of vegetable and animal life, and as indicating the transition of the globe from an unpeopled to a peopled condition. This formation consists of hard quartzose sandstone, certain indurated

slates and limestones, and of the marls, shales, and sandstones known by the name of 'the old red sandstone.' Its fossils consist chiefly of infusory animalcules; corals, shell-fish, and fishes, and of sea-weeds and a few lowly organised terrestrial vegetables. Then comes the *secondary* formation, subdivided into the older and younger; the former comprehending the mountain limestone, coal, bituminous shales, ironstone, clays, and soft thick-bedded sandstones; and the latter the new red sandstone, magnesian limestone, and those calcareous groups known as the lias, oolite, and chalk. In the older secondary, corals, shell-fish, and fishes are exceedingly prevalent; and vegetation during that era was so prolific as to furnish the material of which coal is formed: in the younger secondary, vegetation is less abundant, but shell-fish, fishes, and strange gigantic fish-like reptiles are everywhere to be found, and of forms not now in existence. Next in ascending order lie the beds of the *tertiary* formation, consisting of clays, marls, soft sandstones, limestones, and gypsum; and in which the remains of birds, mammalia, and vegetables somewhat like existing genera are for the first time discovered. Above all these formations are scattered the clays, gravels, sands, peat-mosses, and marls which constitute the *superficial accumulations* of the current era; and in these are found the remains of existing races of plants and animals, some species of which, however, have already become extinct in several regions. Intermingled with these formations—now throwing them up in hills or depressing them in valleys; now overlying them in mountain masses, or breaking and contorting them in the form of veins and dikes—are the igneous rocks, the granites, basalts, and traps of past ages, and the lavas of the present era.

All this succession and accumulation of strata, this appearance and disappearance of different races of plants and animals, indicate the lapse of innumerable ages—ages through which the earth has progressed from phase after phase to that which it now presents. What a strange and checkered history! Nor does it yet present, in any of its physical relations, a single aspect of rest or stability. The conditions of its constitution forbid this; and while we write, rocks are wearing down, rivers are laden with débris, new strata are being deposited, volcanoes are elevating, earthquakes are depressing, and land and sea are gradually changing places, as they have done in all times bygone. All the stratified rocks which we have enumerated have been deposited in the ocean, in estuaries, or in fresh-water lakes; and could we accurately map out the sites and limits of these deposits, we should find that at no two periods in its history has our planet presented the same distribution of land and water. All that we know for certain is, that, from the earliest dawn of the stratified formations up to the current moment, there have been sea and dry land, rains, springs, rivers, and all those degrading and transporting agents which are in incessant operation around us. What the altitude and irregularities of this dry land, what the depth and constitution of this ocean, we may never ascertain. We know, however, that the same rocky material has undergone successive rounds of disintegration and reformation; that this material is essentially made up of silicious, calcareous, argillaceous, bituminous, metallic, and saline constituents, and that these constituents, as well as those of plants and animals, are compounded of about sixty elementary substances; of which, at the ordinary pressure and temperature of the atmosphere, five are *gaseous*, and the rest mostly solid, by far the greater number—at least forty-two—being metals. (See CHEMISTRY.)

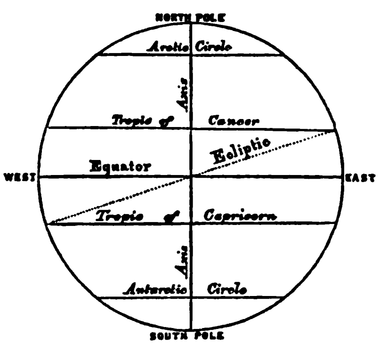
Of the constitution of the ocean, or watery portion of the earth's superficies, chemical research affords us equally accurate data. When pure, water is composed of 1 hydrogen and 8 oxygen by weight, or of 2 hydrogen and 1 oxygen by volume. In motion, however, water is generally found to contain many impurities—such as clay, sand, animal and vegetable matter, &c.—which, if left at rest, by their own weight soon fall to the bottom. Such substances are said to be *mechanically suspended*, and when deposited at the bottom, form sediment. Besides impurities of this description, water may contain matter which will not fall down, and which is said to be held in *chemical solution*. The saline matter in sea-water amounts to about 3½ per cent. of its weight, or nearly half an ounce to the pound. It consists chiefly of common salt, sulphate of soda, chloride of lime, and of magnesia. The saltness of the sea, however, is not quite uniform. In general, it is greater in the trade-wind regions than in extra-tropical; or wherever evaporation exceeds precipitation. A rainless sea, like the Red Sea, is considerably salter than the ocean generally; the Baltic again, which receives a great many rivers, contains only half as much salt as the Atlantic. It is often found that while a comparatively fresh current is flowing one way on the surface, a salter undercurrent is setting in the opposite direction. A knowledge of the constitution of the ocean is necessary to the explanation of numerous facts in geology and biology. The saline constituents must influence more or less all chemical changes, rock deposits, and animal and vegetable life, which take place in the ocean. From these constituents, mollusks and coral animalcules obtain the material of which shell-beds and coral-reefs are constructed; and by this same constitution, marine plants and animals are made to assume external characters which distinguish them from the inhabitants of fresh waters.

The *atmosphere*, the next great constituent of the globe, plays an equally important part in the organic and inorganic economy. Pressing with a weight of about fifteen pounds upon every square inch at the ordinary sea-level, and diminishing in density upwards in geometrical progression, it is evident that animals and plants fitted to live at small elevations will die if removed to great heights—a circumstance corroborated by the fact, that travellers experience difficulty in respiration on very high mountains, and that blood has been known to start from their ears and other tender parts under the diminished pressure. Calculating from data afforded by its density, a limit has been assigned to the atmosphere at the altitude of forty-five miles—or about forty miles above the top of the highest mountains. Notwithstanding its transparency, the air intercepts and reflects the sun's rays, multiplies and propagates them by an infinity of repercussions; and were it not for this property, objects would never be illuminated unless exposed to the direct light of the sun. It is also the recipient and retainer of the solar heat reflected from the earth; and were it not so constituted, the solar rays would be returned to space, and an excessive cold continually prevail. Besides, according to the general physical law, that the capacity of gases for heat increases with their rarity, bodies placed in the upper regions of the atmosphere have their heat so rapidly abstracted, that they are ever beneath the freezing-point; hence the perpetual snows and glaciers of the higher mountains. Chemically speaking, the atmosphere is a gaseous admixture—every hundred parts of which are composed of 79 nitrogen and 21 oxygen—with about one part in 2000 of carbonic acid. In addition to these, which are its permanent constituents, there are always traces of ammonia and a certain amount of aqueous vapour, amounting from 1 to 1·8 per cent.; in certain localities, also minute quantities of other ingredients are to be occasionally detected. The atmosphere may therefore be regarded as the laboratory in which clouds, rain, snow, and other vapours are formed—the medium through which the light and heat of the sun are diffused and equalised—an element without which animal and vegetable life could not exist, for both incessantly inhale and exhale its elements; and an agent indispensable to those innumerable physical operations which constitute the progressive history of our planet.

Thus assisted by the determinations of astronomy, geology, chemistry, and meteorology, as regards the general constitution of the globe, physical geography proceeds to describe and account for its superficial appearance and conditions, and those, again, as influencing the life and distribution of the plants and animals by which it is peopled. Before entering, however, upon these interesting but complicated details, it will be necessary to explain the principal terms and technicalities usually employed by geographers.

GEOGRAPHICAL TERMS.

The direction from which the earth moves in its daily rotation is called the *West;* that towards which it moves, the *East;* the point which is on the right hand of one standing with his back to the east is called the *North;* that on the left hand, the *South.* The imaginary line on which the earth turns is called the *Axis;* its termination towards the north is known as the *North Pole;* that towards the south, the *South Pole.* The early cultivators of geography, dwelling on a part of the earth nearer the north than the south pole, supposed the former to be uppermost, though, in reality, such ideas as upper and under do not belong to astronomy; and it is for this reason that in globes and maps the northern part is always placed at the top, the east being towards the right, and the west towards the left hand, with the south at the bottom. Exactly between the two poles, and consequently dividing the earth into two equal portions, is a line called the *Equator;* all



north and south of which are respectively called Northern and Southern Hemispheres or Half-spheres. In the same way, an encircling line, at right angles to the equator, divides it into Eastern and Western Hemispheres. The circuit of the earth, both in its girth between east and west, and between north and south, is divided into 360 parts, called *degrees,* each degree being equal to about 69½ British miles. At the distance of 23½ of these degrees from the equator, in both directions, are two parallel lines called the *Tropics,* in reference to the sun's declination; known respectively as that of *Cancer* and *Capricorn,* from these constellations being situated in a corresponding part of the sky. At the same distance from each pole is a parallel line—that on the north being styled the *Arctic,* and that on the south, the *Antarctic Circle.* The spaces between the tropics are called *Torrid Zones,* because the sun, being always vertical in some part of that space, produces a greater degree of heat than is felt in regions where his rays strike more obliquely. The spaces between the tropics and the Arctic and Antarctic Circles are styled the *Temperate,* and the spaces within these latter circles, the *Frigid Zones.* Lastly, a line, which cuts the equator obliquely, touching upon opposite points of the tropics, is called the *Ecliptic.* The points where the ecliptic cuts the equator are termed *Equinoctial Points* or *Nodes;* and when the sun is in that part of his course, the day and night are of equal length. These equinoxes of course occur twice during the year—namely, the 21st March and 21st September. The ecliptic and equator are sometimes called *Greater Circles,* because they encircle the earth at the thickest parts; the others above enumerated are all *Lesser Circles.* A series of lines drawn from pole to pole over the earth's surface, and cutting the equator at right angles, are called *Meridians,* from the Latin *meridies,* mid-day. Every place upon the earth is supposed to have one of these passing through it, although it is usual to describe only twenty-four upon the surface of the terrestrial globe. When any of these is opposite the sun, it is then mid-day, or twelve o'clock, with all the places situated on that meridian; and consequently midnight with those on the opposite meridian, on the other side of the earth. Thus, when it is twelve o'clock at noon in any particular part in Britain, it will be twelve o'clock at midnight in a corresponding part on the opposite side of the globe—that is, with our *Antipodes*—near New South Wales; and the intermediate hours, sooner or later, will all lie in the countries between these two points, exactly according to their position or degrees of longitude.

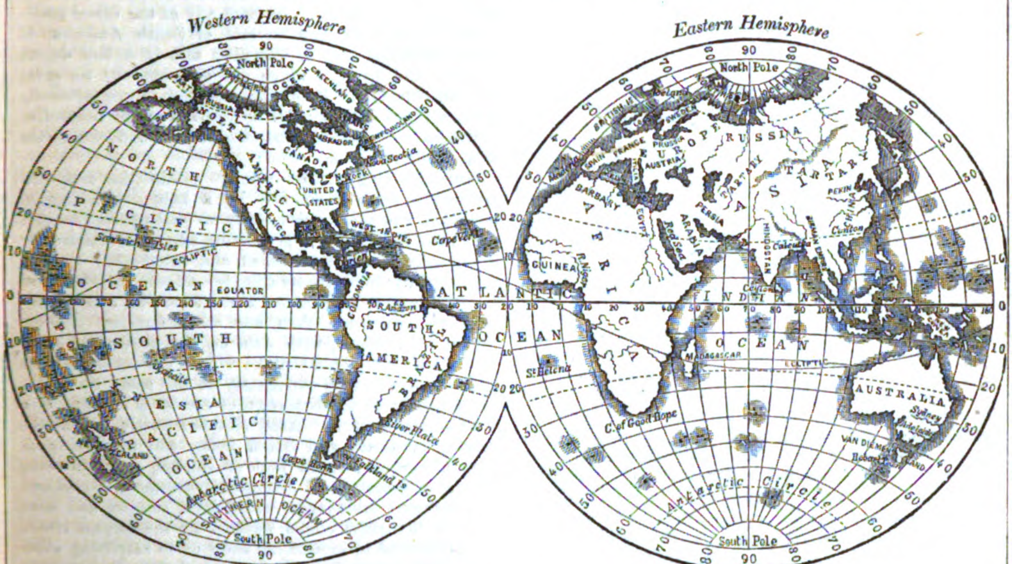
The exact situation of a place upon the earth, or its latitude and longitude, is determined by means of these circles. They are all divided, as already stated, into 360 parts, which parts are called *degrees;* these degrees again into 60 equal parts, called *minutes;* the minute into 60 others, called *seconds;* and so on. They are usually indicated by certain signs—thus, 8° 5′ 7″, is 8 degrees 5 minutes 7 seconds. The *latitude* of a place is its distance measured in that manner from the equator. If it lies north of that line, it is in north latitude; if south of it, in south latitude. There being only 360 degrees in the circumference of the earth, and the distance from the equator to either of the poles being only a fourth part of it, a place can never have more than 90 degrees of north or south latitude. The *longitude* of a place is the distance of its meridian from another, which is called the *first meridian.* The first meridian is quite arbitrary, and it is a matter of indifference through what point we draw it, provided it be settled and well known which one we adopt, so as to prevent mistakes. In Germany, the island of Ferro is generally adopted; in France, the observatory of Paris; and in England, that of Greenwich. Longitude is reckoned either east or west of the first meridian; and 180 is therefore the utmost degree of longitude. Some geographers, however, reckon longitude all the way round the globe. From the meridians all tending to a point at either pole, the degrees of longitude necessarily decrease as we approach these points from the equator.

Besides these terms and technicalities, which refer to the earth as a whole, there are others employed to designate its separate portions of land and water. Thus of the land, a *continent* is any vast region uninterrupted by seas; an *island,* any smaller portion surrounded by water; a *peninsula,* a portion nearly surrounded by water; an *isthmus,* the narrow neck which connects a peninsula with the mainland; a *cape, promontory,* or *headland,* a point of land jutting out into the sea. As to the water, a large uninterrupted extent of sea is called an *ocean;* smaller portions are known as *seas;* a bend of the sea into the land, a *bay;* a deeper indentation, a *gulf;* a narrow strip of sea, a *strait* or *channel;* and where the sea stretches inland to receive the waters of some large river, it is termed a *firth* or *estuary.* Referring to the surface of the land, without any reference to water, extensive flats are known as *plains, steppes, pampas,* &c.; smaller ones as *valleys, straths,* and *dales;* elevated land is spoken of as rising into *hills,* or, still higher, into *mountains;* and level elevated tracts are known by the name of *table-lands* or *plateaux.* Running water makes its appearance in *springs,* many of which conjoined form *streams,* and streams *rivers;* and where these become stagnant, and spread out into inland sheets, they take the name of

lakes. The bounding-line of land and water is termed the *shore*, and the land bordering on the sea in any place is generally spoken of as the *coast* or *sea-board.*

DISTRIBUTION OF LAND AND WATER.

To exhibit the earth's surface at one view, it is usual to map it into two halves or hemispheres—the Eastern comprehending the one great continent of the *Old* World, or that known to the ancients; and the Western, or *New* World, discovered and explored since the close of the fifteenth century. To these, modern geographers add a third—namely, *Oceania*, or the Maritime World, partly situated in both hemispheres, and comprising Australia and the vast groups of islands which stud the Pacific Ocean. It will be seen at one glance that the sea and land are very unequally distributed—that they preserve no regularity of outline or form—and that either is placed indifferently as to position, on the



earth's surface. Many fanciful conjectures have been offered to account for the configuration of the existing continents, but none of them seem to have any foundation in fact. The elevating and depressing causes mentioned under the head of GEOLOGY, are too violent and capricious to leave anything like regularity in their results, while it is a matter of indifference as to the planetary relations and equilibrium of the globe what portion of its surface be land or water. And yet, seeing that everything in nature is regulated with such order and harmony, there may be, though beyond our present means of detection, a progression as to the time and manner in which the various portions of the solid crust shall be elevated into dry land, or submerged beneath the ocean. It has been already stated, on geological authority, that the land and water have frequently changed places—and this changing implies vast revolutions in the kind and amount of the vegetables and animals which people the earth. Did the greater portion of the dry land exist between the tropics, for example, the Fauna and Flora of the world would be essentially different from what obtains at present, and still more so from that which could flourish were that land distributed chiefly in the polar regions. The distribution of land and water, therefore, though unimportant as regards the physical relations of the globe, is all-essential to the character of its life and humanity.

Though we are thus unable to account for the present relative arrangement of sea and land, there is one determining principle sufficiently clear—namely, that so long as the same quantity of water remains on the globe, a fixed amount of space will be required to contain it. If the difference between the elevations and depressions of the solid crust be small—in other words, if the hollows in which lakes and seas are spread out be shallow—their waters must extend over a greater space; and if these hollows be deep, the waters will occupy less extensive areas. The operation of this principle should be borne in mind; for if the inequalities of the land were generally less, the waters would occupy larger spaces, and this more extended area of shallow water would act in various ways. It would render the climate more genial and uniform; and, extending a greater surface to the evaporating power of the sun, rains and atmospheric moisture would be more prevalent. These, again, would influence the amount and kind of animal and vegetable life on dry land; while the shallow waters themselves would be more productive of life—it being a well-known fact that marine plants and animals flourish only at limited depths. Of terraqueous distribution at any former period of the world, we can only infer from the appearances which the surface and rocky strata present; but of the present distribution we have pretty accurate information, with the exception of those inhospitable regions surrounding either pole.

The proportion of dry land to water, as at present known, is about one to three—that is, two-thirds of the whole surface of the globe may be assigned to water. Estimating the entire superficies to contain 198,943,750 square miles, nearly 147,000,000 are occupied by water, and only 51,000,000 by dry land. Others, reckoning the entire area of the globe at 197,000,000 square miles, assign seven-tenths as the proportion of space occupied by the ocean—that is, about 138,000,000 of liquid superficies, and somewhat less than 60,000,000 of solid dry land. Of this land, the greater portion lies in the northern hemisphere, or north of the equator; while south of that line the ocean spreads for thousands of leagues, unbroken by a single islet. It will no doubt greatly alter this estimate should the indications of land within the antarctic circle hereafter prove to be portions of one great polar continent. The following is given as an approximation to the amount of land (in square

miles) in the different latitudinal *zones* of the earth's surface:—

Northern Hemisphere.		*Southern Hemisphere.*	
Arctic Zone,	3,250,000	Antarctic Zone,	———
Temperate Zone,	28,530,000	Temperate Zone,	3,830,000
Torrid Zone,	11,620,000	Torrid Zone,	12,210,000
Total,	43,400,000	Total,	16,040,000

The relative configuration of land and sea, we have said, is so extremely irregular, that no conception can be formed of it unless from the study of a well-constructed map; but whatever the character of this configuration, it exercises a most important influence on the physical operations of the globe, by determining the direction of oceanic and tidal currents, and by modifying the direction and force of waves. Oceanic currents influence the temperature, and consequently the life of the ocean; they carry along with them every species of floating débris—and this they deposit wherever the configuration of the land presents an obstruction. Tides also exercise a powerful transporting influence; they rise to greater or less heights, according as they are obstructed by the outline of the land; and while they sweep headlands and promontories bare, they lay down sand and gravel in sheltered bays. Waves also wear away the land, according as the line of coast obstructs or favours the violence of their progress. Since, therefore, these oceanic agents are wearing away dry land in one quarter, and filling up shallow bays and creeks in another; since rains and rivers are wearing down inland regions, and carrying the material to the sea; and since, moreover, earthquakes and volcanoes are here submerging land, and there elevating the bottom of the ocean—the relative distribution of land and water must be continually fluctuating. However imperceptible this shifting may be—little affected as the existing continents may have been within the historic period, or even within the era of man—still the change goes forward; and we are no more entitled to regard the present distribution as a thing fixed and enduring, than an inhabitant of the old red sandstone era—had any such existed—would have been to declare the then arrangement of land and sea as a thing immutable.

CONTINENTS AND ISLANDS.

The quarters or continents—though, strictly speaking, there are only the two great continents already mentioned—into which it is usual to divide the dry land, are *Europe*, *Asia*, and *Africa*, in the Eastern Hemisphere; North and South *America* in the Western; and *Oceania*—including Australia, Malaysia, and Polynesia—situated partly in both hemispheres. By referring to the map, it will be perceived that there are traces of land still unexplored both in the arctic and antarctic regions; but whether these may be islands or masses worthy to be ranked as new continents, we have yet few means of conjecture. At present, the comparative areas (in square miles) of the established quarters—including their respective islands—are calculated as follows:—

Old World, or Eastern Continent,		31,220,000
Europe,	3,724,000	
Asia,	16,152,000	
Africa,	11,354,000	
New World, or Western Continent,		15,000,000
North America,	8,200,000	
South America,	6,800,000	
Maritime World, or Oceania,		4,632,000

The superficies of this vast expanse presents an amazing diversity of character: some portions being little elevated above the sea-level, others rising into mountains of more than five miles in height; some tracts swampy, others arid; certain regions tame and flat, others diversified by the wildest irregularities; districts teeming, under tropical influences, with life and growth, others buried in the perpetual solitude of ice and snow. This diversity of character forms the especial object of our arrangement and description.

Although the above division into 'quarters' be convenient, and even justifiable enough, yet so much do these sections run into each other, so largely do portions of one or more of them lie within the same parallels, and so frequently are their other conditions akin, that it is not very easy to draw a series of broad and well-marked physical and vital distinctions between them. And yet there is something peculiar in the external conditions of Africa—for example, something in its climate and superficies, its river-systems, its Fauna and Flora—that serves to distinguish it as a whole from any of the other continents. The same may be said of South America, of North America, and of Oceania; and in a less degree of Asia and Europe, which are separated by no great natural boundary. Retaining, therefore, these generally acknowledged divisions, let us glance at their respective positions and superficial characteristics as influencing the vitality of our planet.

Europe—lying almost wholly within the northern temperate zone, diversified by a happy blending of mountain and plain, marked by no geographical feature on a scale so large as to give to its surface the character of monotony, and surrounded and intersected by seas which greatly influence its climate—affords, in proportion to its area, a habitat to a more varied and highly developed existence than any other quarter. Widely connected, however, with Asia on the east, those parts of the two continents that lie within the same parallels present considerable similarity, at the same time that every facility to the dispersion of species is afforded by a land communication. Asia, situated partly within the torrid, temperate, and frozen zones, and presenting an area almost five times that of Europe, exhibits every species of geographical diversity—vast mountain-chains and elevated table-lands, broad level steppes and sand deserts, luxuriant plains watered by the largest rivers, tracts doomed to everlasting snow or to scorching sterility, salubrious valleys of incessant verdure, and noisome jungles of the grossest growth. With such a variety of character, it is impossible to treat of it as a whole, and consequently geographers divide it into five well-marked regions—namely, *Central* Asia, consisting of a series of ascending plateaux, diversified by mountain-ridges of stupendous height, and intersected by narrow valleys; *Northern*, including the whole of the continent north of the Altaï Mountains—a flattish region traversed by large rivers, bleak and barren, suffering under an intense cold, thinly peopled, and almost physically incapable of improvement; *Eastern*—upon the whole a low-lying and somewhat arid region, though traversed by several of the largest rivers in the world, and occasionally diversified by spurs from the central table-heights; *Southern*, including the two peninsular projections of India within and without the Ganges—decidedly the finest region of the continent, diversified by minor hill-ranges and well-watered valleys, enjoying a high, though not an oppressive temperature, having only a rainy season for its winter, and, except during long drought, presenting in every district an unfailing verdure; and, lastly, *Western* Asia—from the Indus westward and north to the Caspian—which, with a few minor exceptions, may be said to consist of high sandy plains, studded with salt-lakes, very inadequately watered by rivers, and on the whole a hot and arid region. A continent marked by such a diversity of surface and climate, presents an appropriate field for the exhibition of almost every form of vitality known in the other continents; and thus has belief ever pointed to it as the cradle of organic existence. Africa, the next great division of the Old World, is almost entirely insular, the isthmus connecting it with Asia being only seventy-two miles across, of no great elevation above the sea-level, and even in part occupied by lakes and salt-marshes. Respecting the physical appearance and construction of Africa, our information is extremely limited; all that is known with any degree of certainty being some patches along the sea-board, and a few tracks

or lines across the Sahara, or Great Desert of the north. Little known, however, as it is, its isolation, its intertropical position, and its general configuration, must stamp it with *vital* peculiarities; and yet its connection with Asia on the one hand, and its proximity to Europe on the other—the Straits of Gibraltar being only about eight miles in width—offer numerous facilities to the interchange of vegetable and animal species. Thus the southern and northern sea-board of the Mediterranean present many similar forms; the Flora and Fauna of Egypt and Nubia are identical in many instances with those of the adjoining tracts of Arabia; while the intertropical regions offer numerous genera allied to those of Burmah and Hindostan.

Turning now to the New World, we find also the two Americas so slenderly attached by the narrow rocky Isthmus of Panama, which at one part is little more than eighteen miles across, that they may safely be regarded as separate and distinct continents. This separation is rendered still more decided by the irregular character of the isthmus and the adjoining high table-land of Mexico, which form an almost impassable barrier to the migration either of animal or of vegetable races. South America lies chiefly within the tropics, a third part or less stretching southward into the temperate zone; its superficies is broadly marked by mountain and plain, exhibiting along the entire western coast a flat arid region, from 50 to 100 miles in breadth; then rising boldly up into the Andes, which stretch along its whole length, and present a rugged irregular region of variable breadth; and ultimately falling away to the north and east in the *llanos* of the Orinoco, the *plains* of the Amazon, and the *pampas* of La Plata. Nor are its physical features more broadly marked than the plants and animals by which it is peopled, these exhibiting typical peculiarities only next in degree above those of the somewhat anomalous continent of Australia. The problem of the north-west passage being now solved, Greenland and a number of islands lying west of it might be conveniently erected into a new geographical division. Following, however, the usual course of including these regions, the area of the known continent of North America may be stated at 8,200,000 square miles—the great mass of which lies within the northern temperate zone. The general physical characteristics of the continent are remarkable for the magnitude of the scale upon which they are presented—the plains, lakes, and rivers being superior to those of all other countries. Though lying chiefly within the temperate zone, its southern and northern regions are respectively placed under tropical and arctic influences; and thus it presents in some measure the threefold variety of Fauna and Flora which characterises the greater continent of Asia. This greater diversity of climate renders it less peculiar in its living forms than the sister continent, at the same time that its proximity to Asia—being separated by Behring's Strait, which is only thirty-six miles broad—renders the immigration of Old-World species by no means improbable.

The *insular portions* of the globe are not less worthy of notice than the continents themselves, though these in reality are but islands of greater extent, washed on all sides by the ocean. Meaning, however, by the term *island* those smaller masses of land lying in the midst of seas and lakes, we find them sometimes solitary, oftener collected into groups or *archipelagoes:* in some cases they are little more than low sand-banks, ledges of rocks, or coral reefs; and in others—rising to a considerable elevation above the surface of the water, and spreading to a considerable extent—they present in miniature all the features of the continents to which they belong. They are often the summits of submarine mountain-chains, and, as such, are intimately connected with each other and with the neighbouring mainland. Many of them are evidently the production of volcanic forces—the dawn of new continents emerging from the waters, as others are the gradually submerging relics of former terrestrial regions. The most important island-groups are the British, Japan, Philippine, and East Indian in the eastern hemisphere; and the West Indian and Polynesian in the western. The largest individual islands (regarding Australia as a continent) are—Borneo, with an area of about 260,000 square miles; Madagascar, 234,000; New Guinea, whose outline is yet imperfectly known; Sumatra, 128,000; Niphon, 109,000; Great Britain, 83,828; Nova Zembla, 25,000; Newfoundland, 57,000; Cuba, 43,400; and Iceland, 30,000 square miles.

Islands, we have said, are either connected with existing continents, are portions of former continents now submerged, or are new and independent elevations. Thus, if an island is of the same geological formation with the adjoining mainland, we must regard it either as a portion separated by depression, or as a belated portion only rising into dry land. In either case, we are bound to consider it in all its relations—vital as well as physical—as belonging to the adjacent continent. Again, islands of totally different formation from that of the nearest continent may in most cases be regarded either as relics of former lands, or as new lands rising into day; and we are not to be startled at the fact of their exhibiting—like Australia—races of plants and animals altogether peculiar. Lastly, with respect to far distant and solitary islets, whether of volcanic origin or not, we must view them as indices of operations past or future, and as proofs of the fact that the sea-bottom presents the same irregularities as the surface of the land—these islets towering above the general configuration like the lofty peaks of existing mountain-ranges.

Such is a brief glance at the partition of the dry land (so far as it is known) into continents and islands—a partition which exercises an all-important influence over organic existence, and which, after all, is dependent on very minute geological operations. A general elevation of the solid crust in the eastern hemisphere, for example, would connect Britain with the continent of Europe, the Lofoden Islands with the Scandinavian peninsula, enlarge the connection between Asia and Africa, elevate the Sunderbunds of the Ganges into a vast plain, the Laccadive and Maldive reefs into extensive islands, and the bed of the Yellow Sea into an alluvial plain. A depression to the same amount, on the other hand, would sever Scandinavia from Europe, lay the Netherlands and part of Central Europe under water, sever Africa from Asia, convert a large portion of Arabia, Egypt, and Northern Africa into an extension of the Mediterranean; in fact, totally overturn the existing relationship of the dry land in the Old World. Similar phenomena would be presented under similar circumstances in the New World; and more strikingly still in connection with the island-groups of the Pacific. Equally important results depend upon the relative positions of the continents and islands. Had South America, unaltered in a single square yard, lain parallel with, instead of crossing, the equator, or had Africa been intersected by seas, as Europe is, it requires no stretch of imagination to conceive the radical difference which their Flora and Fauna would have presented. Whether the present arrangement of continent and island is that which admits of the greatest amount and variety of vital development, is what we have not yet sufficient data to determine; but this we know, that the existing irregularity and varied subjection to arctic, temperate, and tropical influences, are much more favourable to these results than any single influence, however gigantic its operation. Nay, more, as regards man, and the highest aim of creation—the civilisation of man—the present arrangement is of the first importance. The theatre of his operations all arctic, and he would never have risen above the condition of the Laplander or Esquimaux; all antarctic, and behold his condition in that of the miserable Fuegian; all tropical, and see him in a state of languid, enervated, semi-civilisation;

while balanced as conditions are, see his progress mainly in one broad zone, where Chinese, Indian, Persian, Chaldean, Syrian, Egyptian, Greek, Roman, Frank, and Anglo-Saxon have successively or simultaneously figured in the march of improvement.

MOUNTAINS AND TABLE-LANDS.

As elevation above the waters of the ocean is the origin of the dry land, so its most prominent features are those peculiar upheavals known by the name of *hills* and *mountains*. They are the framework, so to speak, upon which the solid crust is built and compacted; they are the immediate results of the elevating forces mentioned under GEOLOGY; and according to their character, so is that of the regions to which they belong, generally speaking, determined. They subserve numerous and important purposes in nature. Rising into regions of perpetual ice, they serve, in hot climates, to temper the air with the breezes generated around their heights; they are the reservoirs of rivers, supplying the shrinking streams, in the dry seasons of the lower countries, with copious torrents from their melting snows; they are in most instances the storehouses of the richest minerals; they increase and diversify the surface of the earth; and, by presenting impassable barriers between opposite regions, they give variety and richness to animal and vegetable life: we say impassable barriers, for the broadest seas are not half so effective in obstructing the dispersion of vegetable and animal life as lofty snow-clad mountains. Seas have their tides and currents, and drifting winds and waves—even the polar seas have their firm ice-fields and drifting ice-floes, on which plants and animals may be borne; but the snow-clad summit is enduringly inapproachable by everything that partakes of vitality.

Isolated mountains of great height are of rare occurrence, and when they do appear, are usually active or recent volcanoes. Hills and mountains, whether rising to the height of 1000 or 20,000 feet, generally appear in chains or ranges, consisting either of one central chain, with branches running off at right angles, or of several chains or ridges running parallel to each other; and in both cases often accompanied by subordinate chains of minor elevation. Several chains constitute what is called a *group;* and several groups, a *system*. Geology views these systems as so many axes of elevation, necessary to the rise of certain formations from the bottom of the ocean; ascertains the direction and centre of the elevating force; explains the phenomenon of 'crag and tail;' speculates on the cause of the steep side being generally turned towards the older formations, while the gradual slope looks towards the newer; and further determines the respective eras when they rose into existence, by examining the nature of the stratified deposits broken through and carried up with the elevatory masses. Thus the Grampians, flanked and crested by no secondary rocks, long preceded the Pyrenees; the Pyrenees the Alps, which displaced the youngest secondary strata; and the Alps, again, had risen into form while the site of Etna was a shallow sea of tertiary deposit. The relative ages of mountain-chains appertain more especially to the province of the geologist; but with their epochs is connected their physiognomy or contour, a subject eminently interesting to the geographer. So persistent is the contour of mountains, whether associated with the primitive, secondary, or more recent formations, that the practised eye of the geologist can generally determine at a glance the era of their upheaval. The bold, but bald and massive heights of a granitic mountain differ widely in aspect from the abrupt and splintery crags and pinnacles of a primitive; while the rounded, undulating, and terraced outline of the secondary trap-hills distinguishes them at once from the conical crateriform heights of the tertiary era. Nor is it in appearance alone that these distinctions are interesting; the cold barren subsoil of a granitic district, altogether independent of elevation, differs as widely in its vegetable exhibitions from those of a fertile and congenial trap, as a cultured garden does from a moorland wild.

Respecting the classification of mountains, various plans have been adopted by continental writers; but most of them are objectionable, as involving geological theories: we shall adhere to that simpler arrangement which takes into account merely their geographical position and connection. Those of Europe have been classified into a number of systems, some of which are continental, others insular. Laying aside minutiæ, the following seem to be distinct and natural:—1. The *Hesperian*, embracing the mountain-ridges of the Spanish peninsula—all of which maintain a wonderful parallelism in position, as well as unity of character, and whose extreme culminating-point is Maladetta, in the Pyrenees, 11,424 feet. 2. The *Gallo-Francian* system, including all the hilly eminences in France which lie to the north of the Garonne, west of the Rhône, and south of the Rhine. None of these are of great age, or of great elevation, the highest being a peak of the Plomb de Cantal, in Auvergne, 6113 feet. 3. The *Alpine* system, embracing all those ridges and branches which radiate from the great Alpine range of Switzerland, such as the Maritime, Cottian, Pennine, Rhetian, Noric, and other Alps; the Apennines in Italy, and the Balkan or Hæmus group in Turkey. This is the great mountain development of Europe, under which, as one system, geographers used to comprehend the whole of the southern groups and chains: the highest or culminating-point is Mont Blanc, in Switzerland, 15,732 feet. 4. The *Hercynio-Carpathian* system, including all the mountains and eminences comprehended between the Rhine, Dnieper, and Danube, the plains of Northern Germany and Western Poland. The highest point in this system is Lomnitz, in the Central Carpathians, 8540 feet. 5. The *Scandinavian*, a system of the highest antiquity, embracing the well-defined chains of Norway, Sweden, and Lapland, the extreme height of which does not much exceed 8000 feet. 6. The *Ural* system or chain, which forms the boundary-line between Europe and Asia, and rises in its highest part to between 5000 and 6000 feet. Lastly, the *Britannic* system, consisting of a number of detached chains, as the Grampians, Cheviots, and Welsh mountains, the highest point of which is Ben Nevis, in Inverness-shire, 4406 feet. All of these systems, as axes of elevation, have long ago become fixed and permanent; none of them has for the last two thousand years shewn symptoms of volcanic activity: Hecla, Vesuvius, and Etna, the only active volcanoes in Europe, seem to point to future upheavals.

The mountains of Asia may be all traced from that vast central plateau already adverted to, which forms, as it were, the nucleus of the continent. Omitting ranges of minor altitude, we may enumerate—the *Altai*, forming the boundary between the Chinese Empire and Siberia, one of the bleakest ranges in the world, stretching unbroken for 500 miles in length, and reaching an extreme altitude of 11,500 feet; the *Yablonoi* and *Stanovoi*, which may be regarded as prolongations of the Altaï, stretching onwards to Behring's Strait, and attaining a height probably not exceeding 6600 feet; the *Khing-khan* range, bounding the Desert of Kobi, extending about 800 miles in length, but of unknown altitude; the *Chang-pe-shan*, skirting the east coast of Manchooria, and rising abruptly from the sea to a height of 5000 feet; the *Pe-ling* and *Yun-ling* ranges, on the west of China Proper, ramifying variously, probably attaining a culminating height of 11,000 or 11,500 feet, and branching southward through Burmah and Anam in several parallel ridges which fall to 4000 and 3000 feet; the great *Himalaya* mass, extending about 1500 miles in length, and from 200 to 250 across, rising from the Indian side by stages of 4000, 8000, and 11,000 feet, to a mean elevation of 18,000 or 20,000 feet, attains in several peaks the height of about 25,000,

in Dhwalagiri 28,000, and in Kinchinjunga 28,176—probably the greatest elevation on the globe; the *Hindoo Coosh*, with their southern ramifications, which may be regarded as prolongations of the Himalaya; the *Thian-chan*, in Central Tatary, rising to an absolute height of 11,000 or 12,000 feet, but only from 3000 to 4000 above the surrounding table-land; and, lastly, the *Tauro-Caucasian* system, diversifying the west of Asia with numerous ridges and peaks, the highest of which is Elburz, 17,796 feet. In connection with these systems and ridges are active volcanoes, as in Kamtchatka, Japan, the Thian-chan ranges, the plateau of Mongolia, &c.; and we are therefore not entitled to regard those so connected as having yet attained their ultimate stage of elevation.

The mountain-systems of Africa are as yet only partially known. The hills of Cape Colony rise from Table Mount, 3582 feet, to the summits of the Nieuveldt and Snieuveldt mountains, in the north of the colony, which are estimated at 7000–10,000 feet; the spaces between the ranges being shrubby *kloofs* or valleys, and broad elevated terraces or *karoos*. Beginning with Cape Colony, one vast table-land, the greatest on the globe, occupies the south of the African continent, stretching on the east as far north as Nubia. The mountain-ranges seen running parallel with the east coast, form the border of this table-land; the highest of them yet seen is Kilimandjaro, between 3° and 4° south latitude, estimated at 20,000 feet. The Abyssinian mountains form a terminating cluster to the range, reaching in the Abba Yared, at the extremity of the table-land, the height of 15,000 feet. The Cameroons, on the west, are above 13,000 feet. On the north, between the Sahara and the Mediterranean, the *Atlas* system is well defined, and here an elevation of 11,400 feet has been ascertained; but some peaks in the chain rise much higher, and are permanently covered with snow—a fact which would seem to indicate an altitude of more than 15,000 feet.

The mountains which traverse South America may be ranked under two systems—the *Cordilleras* or *Andes* proper, and the *Brazilian Andes*. The former, in several parallel chains, extend from the Straits of Magellan to the Caribbean Sea, in many places spreading out over a breadth of several hundred miles, embracing lofty table-lands, containing mountain lakes, and everywhere intersected by steep narrow ravines, passes, and lofty water-falls. At Popayan, the main chain divides into three ridges, one of which, shooting off to the north-west, passes into the Isthmus of Panama; a second separates the valleys of the Cauca and Magdalena; and a third, passing off to the north-east, separates the valley of the Magdalena from the plains of the Meta. The highest summits of the system are in the Chilian Andes, between 37° and 31°, where Aconcagua, the highest volcano in the world, and now believed to be the highest summit of the chain, reaches the elevation of 23,200 feet. Chimborazo and Sorata, in the equatorial and Peruvian Andes, are respectively 21,424 and 21,286. Altogether, the Andes present a most magnificent spectacle to the voyager on the Pacific; the snow, which permanently covers their lofty summits, even under the burning sun of the equator, contrasting beautifully with the deep blue of the sky beyond; while occasionally another contrast is exhibited in vast volumes of smoke and fire, emitted from some of the numerous volcanoes which stud the entire range. The Brazilian mountains occupy a great breadth of country, but seldom exceed an elevation of 6000 feet.

The mountains of North America are scarcely in proportion to the other physical features of that continent, either in point of continuity or of altitude. Regarding the Cordilleras of Panama and Mexico, the Californian or Maritime range, and the Rocky Mountains, as portions of the great system of the *Andes* proper, we have in Guatemala a culminating-point of above 13,000 feet; in the Mexican volcano of Popocatepetl, of 17,735; in the table-land of Mexico, a general height from 4000 to 8000 feet; and in the Californian range, an average altitude of 8000 or 10,000 feet. The *Rocky Mountains*—the greatest and most continuous of the North American chains—rise from 8000 to 10,000, occasionally to 12,000, and only between 52° and 53° north, to 16,000 feet; while the *Alleghanies* reach their extreme height at 6476 feet, and sink down in their branches to 3000 and 2000 feet.

In Oceania we have several minor groups and ranges; but the principal elevations are in detached volcanic heights, the index-fingers, as it were, to future mountain-systems. In Malaysia, the highest known point is Mount Ophir, in Sumatra, 13,850 feet; Australia has no eminences of importance; but Polynesia has the verdant and wooded heights of Tahiti, rising to 8000 feet; and the active craters of Owyhee, above 13,000.

Such are the more prominent mountain-systems as known to geography. Those who regard them as mere ridges, rising on one side, and descending as abruptly on the other, and at most intersected by a few narrow passes, gorges, and ravines, form a very erroneous conception of the physical contour of the globe; for, so far from this being the case, most of these systems are but the escarpments or ramparts of elevated expanses known as *plateaux* or *table-lands*, which form in some instances the nucleus of continents, and the source from which the rivers of such continents flow. Thus, on examining the map of Asia, it will be seen that all the rivers flow—north, east, south, and west—from the central region, which in reality forms a succession of remarkable plateaux. These plateaux may be termed the Persian, which ranges from 3000 to 6000 feet above the sea; the Mongolian, at an elevation of from 8000 to 12,000 feet; and that of Tibet, which reaches 17,000. There are some masses of this kind in Europe, but of comparatively small extent—as the central part of Spain, which is about 2200 feet in height; and the Swiss table-land, between 3000 and 4000 feet. Of the elevation of the great South-African plateau, we cannot speak precisely, but it seems to be highest towards the borders. In South America, the city of Potosi, in Bolivia, is situated in the elevated valley of Desaguadero, at 13,600 feet above the sea-level; and the plateau on which Quito stands has an elevation of 9000 feet. One of the most noted table-lands is that of Mexico, not less remarkable for its elevation than for its extent. 'On the eastern and western coasts are low countries, from which, on journeying into the interior, you immediately begin to ascend, climbing, to all appearance, a succession of lofty mountains. But the whole interior is, in fact, thus raised into the air from 4000 to 8000 feet. The conformation of the country has most important moral and physical results; for while it gives to the table-land, on which the population is chiefly concentrated, a mild, temperate, and healthy climate, unknown in the burning and deadly tracts of low country into which a day's journey may carry the traveller, it also shuts out the former from an easy communication with the sea, and thus deprives it of a ready access to a market for its agricultural productions.' As with the Mexican, so with all other table-lands, according to their latitude and elevation: under the tropics they become theatres for the exhibition of temperate or even of arctic species; while under a temperate zone they are inhabited solely by boreal forms.

EARTHQUAKES AND VOLCANOES.

These are rather agents than effects—rather the cause of geographical diversity than geographical features themselves; and in this respect belong more properly to the province of geology: still, as by far the greater portion of superficial irregularity is the direct result of their operations, and as it is often impossible to separate cause from effect, it will be necessary here to give them some further consideration. An earthquake may produce a momentary undulation of the ground, followed by no perceptible result; it may simply elevate one region or depress another; it may be attended by a vast destruction of animal life, and the submergence of forests; it

may alter the course of rivers, and produce new shores and beaches; it may create vast tidal waves, which give rise to accumulations of débris; open new springs and fissures, from which issue various products differing from those hitherto known in the district. Innumerable instances of such changes could be cited; a few, however, will suffice to convince the reader of the importance of this class of physical agencies:—By the great Chile earthquake of 1822, an immense tract of ground—not less than 100,000 square miles—was permanently elevated from two to six feet above its former level; and part of the bottom of the sea remained bare and dry at high-water, with beds of oysters, muscles, and other shells adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia. By an earthquake in 1819, a tract—the Ullah-bund—in the delta of the Indus, extending nearly fifty miles in length and sixteen in breadth, was upheaved ten feet; while adjoining districts were depressed, and the features of the delta completely altered. The earthquakes of Calabria, which lasted for nearly four years—from 1783 to the end of 1786—produced numerous fissures, landslips, new lakes, ravines, currents of mud, falls of the sea-cliffs, and other changes, which, taken in conjunction, afford one of the finest examples of the complicated alterations which may result from a single series of subterranean movements, even though of no great violence. In 1743, the town of Guatemala, in Mexico, with all its riches, and 8000 families, was swallowed up, and every vestige of its former existence obliterated—the spot being now indicated by a frightful desert, four leagues distant from the present town. In 1692, a similar calamity overtook the town of Port Royal, in Jamaica, when the whole island was frightfully convulsed, and about 1000 acres in the vicinity of the town submerged to the depth of fifty feet.

Volcanic forces act in a similar manner, in as far as they elevate, depress, and break asunder portions of the earth's crust; indeed, earthquakes and volcanic throes, considered as subterranean movements merely, produce precisely the same results. But volcanoes, properly so called, act in another and equally important manner in producing geographical changes. They elevate the crust into long continuous ridges or mountain-chains, form isolated cones, and discharge accumulations of lava, scoriæ, ashes, loose stones, and other igneous débris. Geologists and geographers often amuse themselves by enumerating volcanic vents to the amount of 300 or thereby; but this is of little moment compared with the determination of the centres of elevation to which they belong. In Europe, there appear to be three centres of volcanic action—namely, that of the Levant, to which Etna and Vesuvius belong; that of Iceland, represented by Hecla and the craters of Jan Meyen; and that of the Azores, in the Atlantic. In Asia, there is abundant evidence of volcanic action on the borders of the Mediterranean, the Black Sea, the Caspian, and the Persian Gulf; while along the eastern borders of that continent there is a range not less than 5000 miles in length, and 250 in breadth, including Sumatra, Java, the Eastern Moluccas, and the Philippine Islands; the same range bearing further northward, though less distinctly, for several thousand miles, and terminating in the volcanic cones of the Aleutian Isles. The whole extent of the two Americas is also traversed by a volcanic range, manifesting itself by eruptions along the whole line, from the Rocky Mountains, through Mexico and the Andes, onward to Patagonia and Tierra del Fuego. The islands of the Pacific further attest the presence of similar forces, as in the New Zealand, Sandwich, and other groups; as do those—namely, the Canaries, Cape de Verd, Ascension, St Helena, Madagascar, Bourbon, &c.—which surround the continent of Africa. In these centres of igneous action, many of the volcanoes are *extinct*, others are merely *dormant*, while many are incessantly *active*.

The cause of volcanoes, earthquakes, and other subterranean movements, has been the subject of several theories, but is yet by no means very satisfactorily determined. The most prevalent opinion is that which connects them with one great source of central heat—the residue of that incandescent state in which our globe originally appeared. By this hypothesis it is assumed that the crust of the earth is of various thickness, that it contains vast caverns, and is extensively fissured—primarily by unequal contraction from cooling, and subsequently by subterranean agitations. Through these fissures, water finds its way to the heated mass within; this generates steam and other gases, and these exploding, and struggling to expand, produce earthquakes and agitations, which are rendered more alarming by the cavernous and broken structure of the crust, and the yielding material upon which it rests. Occasionally these vapours make their way through fissures and other apertures as gaseous exhalations, or as hot springs and jets of steam and water, like the geysers of Iceland. On the other hand, when the expansive forces within become so powerful as to break through the earth's crust, discharges of lava, red-hot stones, ashes, dust, steam, and other vapours follow; and repeated discharges of solid material gradually form volcanic cones and mountain-ranges. It does not follow, however, that volcanic discharges must always take place at the point where the greatest internal pressure is exerted, for volumes of expansive vapour press equally upon the crust and upon the fluid mass within, so that the latter will be propelled towards whatever craters or fissures do already exist. This theory of central heat is further supported by the occurrence of igneous phenomena in all regions of the globe, and by the fact that most volcanic centres are in intimate connection with each other—a commotion in one district being usually accompanied by similar disturbances in another. The only other hypothesis which has met with countenance from geologists is that which supposes the internal heat to be the result of chemical action among the materials composing the earth's crust. Some of the metallic bases of the alkalies and earths, as potassium, the moment they touch water, explode, burn, melt, and become converted into red-hot matter, not unlike certain lavas. This fact has given rise to the supposition that such bases may exist within the globe, where, water finding its way to them, they explode and burn, fusing the rocks among which they occur, creating various gases, and producing caverns, fissures, eruptions, and other phenomena attendant upon earthquakes and volcanoes. As yet, our knowledge of the earth's crust at great depths is excessively limited; we know little of the chemical and magnetic operations which may be going forward among its strata; and we are equally ignorant of the transpositions which may take place among its metallic and earthy materials; but, judging from what we do know, this theory, however ingenious, seems by no means adequate to the results produced. It is true that there occurs nothing among the products of volcanoes at variance with its assumptions; but the magnitude, the universality, and the perpetuity of volcanic action, point to a more stable and uniform source—that source being the internal heat or residue of that igneous condition in which our planets originally appeared.

PLAINS—VALLEYS—AND OTHER DEPRESSIONS.

The plains, or level portions of the earth's surface, form a feature in its physical aspect equally important with that presented by its mountain-systems. The name is given to extensive tracts whose surface in the main is level, or but slightly broken by elevations and depressions. They are found at all elevations above the sea, and of every degree of fertility; from the exuberant tropical delta just emerging from the water, to the irreclaimable sterility of the desert of ever-shifting sand. In the economy of nature, they constitute the chief theatres of vitality: there, plants, from the lowliest herbage to the most gigantic timber-trees, flourish in greatest perfection and abundance; there, animals,

governed by food-instincts, congregate most densely; and there, man, led by similar instincts, and by the higher purposes of social life, has chiefly planted his habitation.

The noblest of these expanses are the river-plains of the New World, drained by such waters as the Mississippi, the Amazon, and La Plata. In North America, the basin or drainage of the Mississippi is estimated at 1,300,000 square miles, and that of the St Lawrence at 600,000; while northward of the fiftieth parallel extends an inhospitable flat of perhaps still greater dimensions. Much of the former expanse is rolling or undulating in its surface, well watered by minor rivers, exhibiting broad grassy *prairies* and extensive pine-forests; the second is more irregular in surface, largely occupied by lakes, and cumbered with forest-growth; while the last is a bleak and desolate waste, overspread with innumerable lakes, and resembling Siberia in the physical character of its surface and the rigour of its climate. In South America we have first the low belt of country skirting the shores of the Pacific, from 50 to 100 miles in width, and about 4000 in length, fertile at its extremities, but in the middle sandy and arid; next, the basin of the Orinoco, consisting of extensive plains called *llanos*, either destitute of wood, or merely dotted with trees, but covered during part of the year with tall herbage; then the basin of the Amazon, a vast plain, embracing a surface of nearly 2,000,000 square miles, possessing a rich soil and humid climate, and almost entirely covered with dense forests and impenetrable jungle-marshes by the river-sides; and, lastly, the great Valley of the Plata, occupied chiefly by open plains called *pampas*, in some parts saline and barren, but in general clothed with weeds, thistles, and tall grasses. Next, in order of importance, is that section of Europe extending from the German Sea, through Prussia, Poland, and Russia, towards the Ural Mountains, presenting indifferently tracts of heath, sand, and open pasture, and regarded by geographers as one vast plain. So flat is the general profile of this region, that it has been remarked, 'it is possible to draw a line from London to Moscow, which would not perceptibly vary from a dead level!' Passing the Ural ridge, a plain of still greater dimensions stretches onward through Siberia, towards the shores of the Pacific. This region is of no great elevation, and, though diversified by occasional heights, consists chiefly of gravelly steppes, covered with coarse herbage, lakes, and morasses. In Africa, the northern and central portion, so far as explored, appears to be a vast expanse of Sahara, or sandy desert, broken at scanty intervals by oases of life and verdure.

Besides these wide expanses, which may be said to counterbalance the mountain-systems, there are plains of minor extent, which often stamp the countries to which they belong with a peculiar character. These are the verdant *prairies* of North America, already noticed, the *pampas* and *llanos* of South America, the *steppes* of Asia and Northern Europe, the *tundras* or bog-marshes of Siberia, the grassy *karoos* of Southern Africa, the tangled *jungles* of India, the alluvial *straths* or *dales* of our island, and the low muddy, but gradually increasing *deltas* of such rivers as the Ganges, Nile, Niger, and Mississippi. To lesser flats and depressions—as valleys, glens, ravines, &c.—which give character to the landscape of minor districts, our space will not permit us to refer. Physically, they produce results akin to those of larger depressions; and whether they be the subsidences occasioned by earthquakes, the sites of silted-up lakes, valleys of erosion, or ravines of volcanic rupture, it is the province of geology, not of geography, to determine.

Under this head it is usual to describe *fissures*, *caverns*, and other *subterranean* openings; but as these are interesting more on account of their curious structures, than from any effect they produce on the aspect or conditions of the globe, we shall leave them to be noticed, as occasion may offer, under the respective countries in which they occur. This only we may observe, that they owe their formation either to earthquakes and volcanic convulsions, to the erosion of subterranean springs and streams, or to the action of waves and tides, when the cliffs in which they are situated formed the shores of the ocean. They become indices, in this way, to bygone operations; and are not unfrequently the catacombs, as it were, of animals long ago extinct, whose remains had either been drifted thither, or who, while alive, had fled there for a last shelter during some of nature's extraordinary convulsions.

THE OCEAN.

The ocean, though in fact a single mass of fluid resting in the hollows of the solid crust, surrounding the dry land on all sides, and indenting it with numerous bays and gulfs, is generally divided by geographers into the following great basins:—The *Pacific* Ocean, 11,000 miles in length from east to west, and 8000 in breadth, covering an area of 50,000,000 square miles; the *Atlantic*, 8600 miles in length from north to south, and from 1800 to 5400 in breadth, covering about 25,000,000 square miles; the *Indian* Ocean, lying between 40° south, and 25° north latitude, is about 4500 miles in length, and as many in breadth, covering a surface of 17,000,000 square miles; the *Antarctic* Ocean, lying round the south pole, and joining the Indian Ocean in the latitude of 40° south, and the Pacific in 50°, embraces an area—inclusive of whatever land it may contain—of 30,000,000 square miles; and the *Arctic* Ocean, which surrounds the north pole, and lies to the north of Asia and America, having a circuit of about 8400 miles. Besides these great basins, there are other *seas* of considerable extent, as the Mediterranean, covering an area of 1,000,000 square miles; the German Ocean, 153,700; the Baltic, 134,900; the Black Sea, with its subordinate gulfs and branches, 181,000; but these, and other minor sections, will be more appropriately described when we come to treat of the respective countries (Volume II.) with which they are politically as well as physically associated.

Respecting the *depth* of the ocean, we have no very definite knowledge; but this we may assume, *a priori*, that it possesses great irregularity of depth and shallowness, just as the terrestrial surface presents diversity of hill and plain. It is also thought probable, considering the greater extent of the ocean than of the land, that the greatest depths of the former may considerably exceed the greatest elevations of the latter; and this would seem to be borne out by recent deep-sea soundings, if their accuracy could be depended upon. In the North Atlantic, 31° 59′ north latitude, 58° 43′ west longitude, no bottom was found with a line of 34,200 feet, or 5·6 geographical miles; but in 36° 49′ south latitude, 37° 6′ west longitude, bottom was found at the depth of 46,236 feet, or 7·6 geographical miles. Lieutenant Maury believes the greatest depth yet surely ascertained, to be not more than 25,000 feet. The deepest place in the North Atlantic is immediately to the south of the Grand Banks of Newfoundland. Having nearly ascertained its superficies, and assuming average depths, many have amused themselves with calculating the probable quantity of water in the ocean; but all such calculations, in the absence of anything like data, are worse than worthless. This only we know, that the quantity, whatever it may be, remains, by the unalterable laws of evaporation and condensation, always at a fixed point, there being neither increase nor decrease. It has been remarked by La Place, a French astronomer, that if the existing waters of the ocean were increased only one-fourth, the earth would be drowned, with the exception of some of the highest mountains; and that if, on the other hand, the waters were diminished in the same proportion, the largest rivers would dwindle to the capacity of brooks, and some of the principal arms of the sea would entirely disappear, while at the same time the earth would be deprived of its due proportion

of humidity, and the face of nature be dried up and rendered desolate. The *pressure* of the ocean—which depends on its depth—exerts an important influence, inasmuch as it renders it impossible for plants or animals to exist beyond a comparatively limited distance from the shore or depth from the surface. Teeming as the ocean is with life, its greater depths seem to be as void and desolate as the peaks of the snow-clad mountains.

Water being a slow conductor of heat, the *temperature* of the ocean is less affected by seasonal influences, and much more uniform, than that of the atmosphere; while the action of currents and counter-currents tends to equalise its heat in all latitudes. Within the tropics, the surface-temperature ranges between 77° and 84° Fahrenheit; but at the depth of 300 feet or thereby, the solar influence is unfelt. In the torrid zone, the temperature diminishes with the depth; in the polar seas, it increases with the depth; and about the latitude of 70°, it is nearly constant at all depths. Taking the month of March as one of those during which the heat of the sun must be equally determined in both directions by latitude, we find that in that month the sea has been found, at 11° 32′ south, of 80·6 Fahrenheit; at 31° 34′ south, of 75·7; at 40° 36′ south, of 59·9; though in some instances it has been found several degrees more or less at the same season, and under nearly the same latitude. A small difference is discovered between the observations on temperature in the two hemispheres. For the first twenty-five degrees towards the south, the decrease of heat is slower, and after that more rapid, than towards the north. It must be evident to every one who considers the great mass of waters composing the ocean, and the interchange of position which must always be taking place, to a greater or less extent, between the warmer and colder portions, that this comparative equability of temperature is unavoidable, even if there were no other causes to account for it. The uses of that equability are still more obvious: by it the natural result of high latitude is more or less corrected. A milder air breathing from the sea softens the climate all over the adjacent land, and produces a congeniality which is of the greatest service. On the other hand, in those torrid regions where both animated and vegetable nature is apt to sink beneath the vertical rays of the sun, the cooling breath of the ocean comes, generally at regular intervals, communicating freshness and vigour to all around.

The *saline property* of the ocean, to which we have already adverted in general terms (p. 51), has never been scientifically accounted for; it baffles all human investigation. Some have alleged that it is caused by fossil or rock salt at the bottom; others, that the saline constituents are carried down by springs and rivers from the land; but neither hypothesis will account for all the phenomena; while, if the latter were true, the ocean would be gradually becoming salter in consequence of incessant contributions. The most reasonable conclusion is, that the sea has been from the first a salt body; that its waters were created, and have continued, and ever will continue, in this saline condition, in the same manner that the atmosphere has been created and exists as a compound body. The inquiry, therefore, why the sea is salt, is just as needless as why the atmosphere is composed of two or three gases. The two questions are equally shrouded in mystery. All that we know for certain is, that the ocean is not of uniform saltness; that the Southern Ocean, for example, contains more than the Northern; that inland seas are sometimes more, sometimes less, saline than the open ocean; and that the surface-water is somewhat fresher than that obtained from considerable depths. The gravity conferred on the water of the ocean by its saline property is 1·027, reckoning distilled water at 60° Fahrenheit equal to 1; and to this density it owes its superior buoyant powers. Again, fresh water, under ordinary circumstances, freezes at 32° Fahrenheit, whereas the water of the ocean requires a degree of cold equal to 28°; and the ice then formed is irregular, porous, and charged with vesicles full of a dense briny liquid.

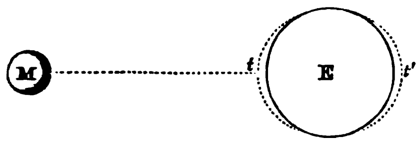
The *colour* and *phosphorescence* of the ocean are the next sensible properties requiring attention. When examined in small quantities, sea-water is colourless; but when viewed in the mass in the wide ocean, it appears to be of an azure or blue tint. The cause of this generally blue colour has not been as yet clearly explained; but it seems to be in some degree accounted for by reference to certain principles connected with the science of optics. Probably most are aware that light consists of the set of colours which we see so beautifully displayed in the rainbow. Now, it is a law of light, that when it enters any body, and is either reflected or transmitted to the eye, a certain portion of it, consisting of more or less of its colours, is lost in the body. The remainder, being reflected, strikes our vision, and whatever colour that may be, the object seems of that colour. Now, it chances that the portion of light most apt to be reflected from masses of transparent fluid is the blue; hence it is supposed to be that the air and sea both appear of this colour. While there can be no doubt that the ocean is generally of a blue colour, it is equally certain that there are many portions of sea in which a different hue appears. The causes of those exceptions from the rule seem to be of various kinds. Frequently the ordinary colour of the sea is affected by the admixture of foreign substances, these being sometimes of a living and organic nature, and sometimes not. The most simple example of the latter class of cases is the common flooding of any stream, when quantities of mud and earthy particles are introduced into the river, and emptied into the sea. What is thus strikingly seen on every coast, on a small scale, will readily be conceived to be of infinitely wider extent in the mighty rivers of the principal continents of the globe. Some seas are coloured *yellow* from a similar cause. Vegetable matter is known to have a colouring effect; but more usually the peculiar tint, whether red, green, &c., of the sea, results from the presence of infusorial animalcules. Another class of cases in which the ocean appears to be tinged with a peculiar colour, is referable to the reflection of rays of light from the bed or bottom; and hence, in shallow and clear seas, the colour of the ground is a main cause of any particular tint which the water may there assume.

The phosphorescence of the ocean, described in such glowing terms by almost every voyager in tropical seas, is now satisfactorily ascertained to arise sometimes from the presence of infusorial animalcules, and at others from the decomposition of vegetable and animal matter. Similar phenomena, arising from similar causes, exist on land—the glowworm, firefly, certain fungi, putrid fish, &c.—and their appearance in the one element need not excite greater surprise than their exhibition in the other.

TIDES—CURRENTS—WAVES.

The waters of the ocean are subject to various motions and fluctuations, such as tides, currents, whirlpools, waves. That regular ebb and flow known by the name of *tides*, and which confers on the ocean one of its most interesting features, is caused by the attraction of the sun and moon. By the universal law of gravitation, all masses of matter have a tendency to be attracted or drawn towards each other. The moon, therefore, as a mass of matter, in passing round the earth, has a tendency to draw the earth after it, or out of its natural relative position; and it really does so to a small extent. As it passes round, it draws up the waters in a protuberance, or, in common language, draws a huge wave after it. But it also draws the whole solid globe—though to a less extent than the water immediately under it—and so causes the opposite side of the globe to be drawn away from the ocean, leaving the waters

there to form a similar protuberance or high wave. In the one case, the water is drawn directly up or towards the moon (M); in the other, the water is in some shape



left behind by the land being pulled away from it. In both a similar effect is produced: two tides (*t*, *t'*) are caused at opposite extremities of the earth. Where the higher part of either of these great billows strikes our coasts, we have the phenomenon of high-water; and when the lower touches us, it is low-water. Each of the waves is brought over any given place in the circumference of the earth in twenty-four hours, so as to cause high-water twice a day. The sun exerts a far greater attractive influence on the earth than the moon does; but from the great distance of that luminary, the *difference* of that attractive force on different parts of the globe is much less, and therefore the effect is comparatively small. But when this minor influence of the sun coincides with that of the moon, or acts in the same line of attraction (M*t*), we perceive a marked increase in the tides; on such occasions we have what are called *spring* or *large* tides. When the solar and lunar attractions act in opposition, we have *neap* or *small* tides. The spring-tides happen twice a month, when the moon is at full and change; and the neap when the moon is in the middle of its orbit between those two points. A tide requires six hours to rise—which it does by small impulses or ripplings of the water on the shore—and six hours to ebb or fall; but every successive high-water is from twenty to twenty-seven minutes later than the preceding, or, on an average, about fifty minutes for two tides, in consequence of the earth requiring that time above the twenty-four hours to bring any given point again beneath the moon. The tides are thus retarded by the same reason that makes the moon rise fifty minutes later every day. It is evident that the tides will be greatest at that point of the earth's surface which is nearest to the moon, or where the latter is vertical. She is so between the tropics; and accordingly the tides are there greatest, and they diminish as we approach either pole. It is further to be remarked, that the moon does not anywhere draw up the tides immediately. Three hours elapse before the waters are raised, in consequence of the law of inertia, or a disposition which every body has to continue in the condition of rest or motion in which it happens to be placed. This stubbornness to resist the moon's influence is only overcome by a three hours' action upon the waters; and thus the tidal wave is always three hours behind the moon in its passage. In some of the firths or arms of the sea on the east coast of Scotland, it has been occasionally noticed that there have been four high-waters in the twenty-four hours. These, however, are not simple tides. The double risings are caused by the irregular passage of the tidal wave from the Atlantic round the north and south points of the island of Great Britain. When that portion of the wave which proceeds by the south reaches the east coast sooner than that by the north, or *vice versâ*, there will be two risings of the water instead of one. Moreover, in consequence of all the great seas and oceans forming, as we have seen, only one sheet of water variously distributed, the ebb and flow in each depend not on its own proper tide, but are the result of the combination of that tide with currents mingling with it from tides of other seas—a result depending upon inequalities of sea-bottom, the configuration of its coasts, their inclination under water, the size and direction of the channel which connects it with other seas, and occasionally upon winds and currents which are not tidal. So much do these circumstances affect the astronomical or *primary* tidal wave, that while it rises in the expanse of the Pacific to one or two feet only, the *derived* wave often rises in confined or obstructed seas to elevations of thirty, forty, or even seventy feet! This circumstance has given rise to the determination of *cotidal* lines, or lines which mark the contemporaneous position of the various points of the great wave which carries high-water from shore to shore. Inland expanses of water, like the Baltic, Mediterranean, and Caspian Seas, and the lakes of North America, have no perceptible tides.

Besides being affected by the regular motion of the tides, the ocean is pervaded by a system of *currents*, mostly constant, which has been compared to the circulation of the blood. These currents play a most important part in modifying the climates of different regions; the subject is also full of practical interest for navigation, and the chief states of Europe and America have agreed to co-operate for its due investigation. As respects the causes of oceanic currents, much remains to be cleared up; but some of the leading causes seem well established. The great disturber of the equilibrium of the ocean is the heat of the sun, so unequally distributed over the earth's surface. This acts in various ways. In one region the waters are expanded by heat, and rendered light; while in another they are condensed by cold, and made heavy. Over one tract, a hot thirsty wind scoops up in a few days a foot deep of water from the surface and precipitates it in one day perhaps over another tract. And wherever evaporation exceeds the fall of rain, there the water becomes salter, and therefore heavier, than that of the ocean generally. From the operation of these causes, we should expect a regular system of currents between the tropical regions and the poles, the lighter water flowing one way on the surface, the heavier below, and in the opposite direction; and such on the whole is found in fact to be the case. Motion once thus begun, however, is differently modified in each locality by the shape of the coasts, by prevalent winds, and other circumstances. But one cause which modifies all currents that tend either north or south, is the daily rotation of the earth. At the equator, any spot on the surface is moving eastward at the rate of 1000 miles an hour; at 60° north latitude, the velocity is only one half. Thus, the water of a current starting from the equator northwards, is constantly coming to places where the bottom under it has less and less eastward velocity. But, by the law of inertia, the water tends to retain the same velocity eastward with which it started, and thus it moves to the east of north—shooting ahead, as it were, of the bottom over which it is flowing, as a rider does whose horse slackens his pace. The contrary happens to a stream flowing from north to south. In this case, the eastward motion or motal inertia of the water is too slow for the parts of the bottom to which it successively comes; the bottom slips in a manner from under it, and it falls to west of south. This, in combination with the action of opposing coasts, accounts for the circular sweep which many of the currents make, returning partly into themselves.

The mightiest and best known of all oceanic currents is the Gulf Stream. 'There is,' says Lieutenant Maury, in his *Physical Geography of the Sea*, 'a river in the ocean. In the severest droughts it never fails, and in the mightiest floods it never overflows. Its banks and its bottom are of cold water, while its current is of warm. The Gulf of Mexico is its fountain, and its mouth is in the arctic seas. There is in the world no such majestic flow of waters.' Issuing through the straits or Gulf of Florida, between Florida and the Bahamas, it proceeds northward nearly parallel to the American coast, to the 35th degree of latitude; then bends gradually eastward, passing over the southern extremity of the Bank of Newfoundland, gradually expanding in breadth, and becoming shallower. Part of its water seems to turn southwards by the Azores; but the great body, according to Maury,

proceeds towards the British Islands, whose shores are bathed by it, and finds its way between Iceland and Scandinavia, into the arctic basin of Spitzbergen. The velocity of this current is about four miles an hour when it issues from the strait, but gradually diminishes. The temperature of the stream when it starts is 86°, and even after travelling 3000 miles to the north, as high as the Banks, there is a difference, in a winter day, between its water and that of the surrounding ocean, of 20° or 30°. It thus carries the warmth of summer into the midst of winter, and occasions the fogs that are so frequent in its northern course. Proofs of its reaching the west of Europe are seen in the drift-wood, seeds, and fruits from the West Indies frequently cast ashore on the west coasts of Ireland, the Hebrides, and Norway. But more important is the effect it produces on the climate of those countries. 'It spreads itself out for thousands of leagues over the cold waters around, and covers the ocean with a mantle of warmth that serves so much to mitigate in Europe the rigours of winter. It is the influence of this stream upon climate that makes Erin the "Emerald Isle of the Sea," and that clothes the shores of Albion in evergreen robes; while in the same latitude, on the opposite side of the Atlantic, the coasts of Labrador are fast bound in fetters of ice.'

Besides the Gulf Stream, a great *equatorial current* flows in the Atlantic from the west coast of Africa to the opposite coast of Brazil, where it is divided into two—one proceeding south along the coast; the other turning north, and entering the Caribbean Sea, where it helps to feed the Gulf Stream. A part of the waters of the Gulf Stream are deflected southward along the west of Europe, apparently to join this equatorial current; and thus there is formed a great whirl. In the middle of the vortex, westward from the Canaries, an immense tract of the ocean is covered with sea-weed (*fucus natans*), in many places so closely that it seems to the eye substantial enough to walk upon. This is the Sargasso Sea of the Portuguese.

The currents of the Pacific Ocean are little known; but the Indian Ocean, exposed to a tropical sun and hemmed in on the north, sends out several large currents of warm water. One is the Mozambique current; another escapes through the Straits of Malacca, and flows past China and Japan into the Pacific, making for the north-west coast of America. This current resembles in many respects the Gulf Stream.

Two currents of equal force, but of different directions, meeting in a narrow passage or gut, will cause a *whirlpool*, a phenomenon which has ignorantly been said to be produced by subterranean rivers, gulfs, chasms, &c., but essentially is only an eddy. Charybdis, in the Straits of Sicily, and the Maëlstrom, on the coast of Norway, are eddies of this kind, alternately absorbing and casting up again whatever approaches them.

Being an elastic and mobile fluid, water is readily acted upon by winds; and thus *waves* are produced, varying in height and velocity according to the force and continuity of the wind, extent of uninterrupted surface, depth of the ocean, contending currents, and the like. 'The common cause of waves,' says Dr Arnott, 'is the friction of the wind upon the surface of the water. Little ridges or elevations first appear, which, by continuance of the force, gradually increase until they become the rolling mountains seen where the winds sweep over a great extent of water. In rounding the Cape of Good Hope, waves are met with, or rather a swell, so vast, that a few ridges and a few depressions occupy the extent of a mile. But these are not so dangerous to ships as a *shorter* sea, as it is termed, with more perpendicular waves. The slope in the former is so gentle, that the rising and falling are scarcely felt; while the latter, by the sudden tossing of the vessel, is often destructive. When a ship is sailing before the wind, and riding over the *long swell*, she advances as if by leaps; for while each wave passes, she is first descending headlong on its front, acquiring a velocity so wild, that she can scarcely be steered; and soon after, when the wave has glided under her, she is climbing on its back, and her motion is slackened almost to rest before the following wave arrives. The velocity of waves has relation to their magnitude. The large waves just spoken of proceed at the rate of from thirty to forty miles an hour. It is a vulgar belief that the water itself advances with the speed of the wave; but in fact the *form* only advances, while the *substance*, except a little spray above, remains rising and falling in the same place with the regularity of a pendulum. A wave of water, in this respect, is exactly imitated by the wave running along a stretched rope when one end is shaken; or by the mimic waves of our theatres, which are generally undulations of long pieces of carpet, moved by attendants. But when a wave reaches a shallow bank or beach, the water becomes really progressive; for then, as it cannot sink directly downwards, it falls over and forwards, seeking the level.' Sailors and others speak of waves running 'mountains high;' but it is questionable if, even in the dreaded Bay of Biscay, they ever attain an altitude of thirty feet, measuring from the trough of the sea to the crest of the succeeding wave.

LAKES AND RIVERS.

Lakes are inland bodies of water not connected with the ocean or any of its branches: they are generally fresh, but are occasionally brackish, or even decidedly salt. They are classified according as they are fresh or saline, and according to the manner in which they receive and discharge their waters—namely, those that both receive and discharge running water; those that receive waters, but have no visible outlet, as the Caspian Sea; those which receive no running water (being fed by springs), but have an outlet; and such as neither receive nor discharge running water. Lakes are distributed over the globe according to the inequalities of surface; and all tend to annihilation, partly by silting up their basins, and partly by deepening their outlets, thereby effecting an entire drainage of their waters. By far the most gigantic are those of North America—such as Superior, Huron, Michigan, Erie, and Ontario, which respectively occupy 35,000, 20,000, 16,000, 10,000, and 7200 square miles. Next in order are the lakes of Asia, of which the largest are Aral and Baikal; the surface of the former is estimated at 23,000, and the latter at 15,000 square miles. Of the African lakes we have no definite information; but Europe can boast of a vast number, which, though generally small, give beauty and diversity to her landscapes. Those of Ladoga and Onega, in Russia, are the largest; the former having a surface of 6330, and the latter of 3280 square miles. A comparative estimate of the extent of these vast sheets may be formed, when we mention that the area of Lake Geneva does not exceed 340 square miles.

Lakes subserve important purposes in the economy of nature. They serve as reservoirs for the waters which rivers would too speedily carry away from the land; they are the tanks, as it were, in which the impurities of streams subside; they refresh and enliven the landscape; and as they all tend to silt up their own sites, these sites become in time tracts of fertile alluvium, and such has been the origin of some of our finest plains. They are also the scenes of extensive and varied vital operations. The plants which spring from their bottoms, or flourish by their margins, differ widely from true terrestrial and maritime vegetation; while the animals which people their waters exhibit peculiarities not less distinct and characteristic.

Rivers, streams, springs—whether flowing with a volume several miles in breadth, or trickling in a tiny rill which a child's hand might obstruct—constitute a class of the most valuable agencies in the physical history of our globe. They are the irrigators of its surface, adding alike to the beauty of the landscape and the

fertility of the soil; they carry off impurities and every sort of waste débris, to be deposited in the ocean as the strata of future continents; and when of sufficient volume, they form the most available of all channels of communication with the interior of continents. Man has ever located himself by their banks—using their waters for his domestic purposes, making their bosoms the highway of his commerce, and applying the force of their currents to the abridgment of his toil. They have ever been things of vitality and beauty to the poet, silent monitors to the moralist, and agents of comfort and civilisation to all mankind. The manner of their origin is this: The sun's heat, acting upon the ocean and other exposed surfaces of water, converts that element into vapour; this vapour, invisible, and of less specific gravity than the atmosphere, ascends, and forms clouds, mists, &c.; and when condensed by cold or other agency, as described under METEOROLOGY, falls by its specific gravity to the surface in the form of dew, rain, hail, and snow. Falling on the surface indiscriminately, these percolate the soil, find their way through the rents, fissures, and pores of the rocky strata, and ultimately escape at some lower level in the form of *springs*. Some of these springs are perennial, others temporary or intermittent: some are limpid, and almost absolutely pure; others are impregnated with metallic, earthy, and saline ingredients, according to the nature of the strata through which they have percolated: some are cold, others tepid; while many issue, with bubbling and steam, near the ordinary boiling-point of water. Springs, naturally tending to lower levels, unite and form *streams;* and these, again, falling still lower, conjoin in valleys, and form *rivers*—creating in their course rapids, cataracts, and water-falls, ravines and dells, lakes, swamps, and marshes, alluvial plains, and low terminating deltas. The valley in which a river flows is usually termed its *basin;* and its *drainage* is that portion of country drained by its streams or tributaries. To compare merely the lengths of rivers is far from conveying a correct idea either of their physical or economical importance; the extent of their basins is an equally important item. The following is a comparative view of the length and drainage of some of the principal rivers on the globe, headed by the Thames as a standard of comparison. The measurements are stated in geographical miles of sixty to a degree. The geographical mile contains 6086 feet, and the British statute mile 5280 feet.

PRINCIPAL RIVERS.		Length in Miles (geog.).	Drainage in Square Miles (geog.).
EUROPE,	Thames,	192	5,000
	Vistula,	520	56,640
	Loire,	520	33,940
	Rhine,	600	65,280
	Elbe,	684	41,860
	Don,	960	163,420
	Dnieper,	1080	169,680
	Danube,	1496	234,080
	Volga,	1800	400,000
ASIA,	Euphrates,	1492	195,680
	Indus,	1960	312,000
	Ganges,	1680	432,480
	Yang-tze-kiang,	2880	547,800
	Amoor,	2380	582,880
	Obi,	2320	924,800
AFRICA,	Nile,	2240	520,200
AMERICA,	St Lawrence,	1800	457,000
	Mississippi—Missouri,	3560	982,400
	La Plata,	1920	886,400
	Amazon,	3080	1,512,000

CLIMATOLOGY.

The climatology of the globe relates to the degree of heat and cold to which its respective countries are subject, the dryness and moisture of the air, and its salubrity or insalubrity as influenced by these and other causes. As yet the minutiæ of climate are but imperfectly determined; the following general causes, however, have been sufficiently ascertained:—1. The action of the sun upon the soil and atmosphere; 2. The internal heat of the globe; 3. The height of the place above the sea; 4. The general exposure of the region; 5. The direction of its mountains relatively to the cardinal points; 6. The neighbourhood of the sea, and its relative position; 7. The geological character of the soil; 8. The degree of cultivation which it has received, and the density of the population collected upon it; and 9. The prevalent winds. These causes, acting together or separately, determine the character of a climate as moist and warm, moist and cold, dry and warm, dry and cold, &c.; and this climatic character is the main influence which determines the nature and amount of vegetable and animal development.

The torrid zone has two seasons—the wet and the dry. The latter is considered as the summer, and the former as the winter of the regions within this zone; but they are in direct opposition to the astronomical seasons, as the rains follow the sun. In some districts, there are two rainy and two dry seasons every year. In the temperate zones, the year is divided into the four seasons whose changes are so agreeable and salubrious. This regular succession of the annual changes, however, can hardly be considered as extending further than from 35° to 60° of latitude. In the frigid zones, two seasons only are known—a long and severe winter, and a short but fervid summer. This abrupt and harsh transition is occasioned by the great length of the day in summer, when the sun never sets, and by the total absence of that luminary in winter. The decrease of heat as we recede from the equator is greater in the southern than in the northern hemisphere. According to Humboldt, continents and large islands, as a general rule, are warmer on their western than on their eastern sides. The extremes of temperature are more felt in large inland tracts than in islands and situations near the coast. The sea absorbs and radiates heat more slowly than the land; and thus after the land has lost its warmth, the ocean is radiating its tempering influences. For these reasons, climatologists have found it necessary to construct *isothermal lines* round the globe; that is, lines along which the annual mean temperature is the same. Again, places which have the same mean annual temperature vary considerably in their mean summer and winter temperature; hence *isochimenal* lines, or lines of equal winter temperature, and *isotheral* lines, or those which shew equal summer over points upon different isothermal curves. Another set of lines or curves, called *isogeothermal*, connect points where the temperature of the soil is equal at or beneath the surface.

Since the temperature of the atmosphere diminishes with the altitude, a limit must be reached where water will remain in perpetual congelation, independent of all seasonal influences. This limit is called the *snow-line*, and is found at various heights, according to latitude, proximity to the sea, and other causes, which affect the general climate of the region. In the Himalaya and Andes, it is found at an elevation of about 17,000 feet; in the Swiss Alps, at 8500 feet; and in the Scandinavian range, at 3500 feet. Generally in those countries which are near the equator, the snow-line is found about 16,000 feet, or three miles above the sea-level; about the 45th parallel in either hemisphere, it occurs at an elevation of 9000 feet; under 60° of latitude, at 5000 feet or thereby; under 70° of latitude, at 1000 feet; and under 80°, the snow-line comes down to the mean sea-level, for countries which are 10° distant from the poles are covered with snow all the year round. From snow and glacier clad mountains cold breezes rush down to cool the adjacent plains; and similar winds blow from the arctic to the tropical regions. Indeed, wherever the air of one region becomes heated or rarefied, the colder and heavier air of the surrounding regions will rush in to restore the balance. Such is the cause of all aërial currents, and in particular of those blowing within the

25th degree of latitude on either side the equator, known as the *trade-winds*. *Monsoons*, the *simoom*, *harmattan*, *sirocco*, and other local winds, *sea and land breezes*, and in fact every species of aërial current, may be traced to similar causes. (See METEOROLOGY.)

The amount of *rain* which falls on the earth's surface is exceedingly varied, ranging from twenty or thirty inches to several feet per annum, and that within comparatively short distances. On the east coast of Great Britain, the average fall is about twenty-four inches; in some parts of the mountains of Cumberland, it reaches 100 inches. The greatest amount of rain recorded is among the Khasia Mountains, to the north-east of Calcutta; at the Churra station, 500 inches have been measured in seven months, and the single month of August has given twenty-two feet. But the moisture of a climate does not wholly depend upon the amount of rain registered by a rain-gauge; for some climates are humid, and yet not rainy; others dry, and yet subject to periodical torrents. These torrents give rise to inundations; hence the peculiar seasonal floodings of such rivers as the Nile and Ganges. The mean annual fall of rain on the entire surface of the earth is estimated at five feet.

DISTRIBUTION OF PLANTS AND ANIMALS.

The *life* of the globe—that is, its vegetable and animal productions—constitutes its most important and exalted feature as a creation. All the varied materials of which it is composed, all the complicated actions, reactions, and mutations to which they are subject, are humble phenomena compared with the production of the lowliest organism. This life is everywhere: the waters teem with it, the dry land from pole to pole is clad with it; nay, there is life within life, and perhaps there exists not a single plant or animal but becomes in turn an abode for others of more diminutive dimensions. Speculations as to the origin and generic classification of vegetable and animal life belong not to our subject. Geography views them simply as they exist, and endeavours to determine the laws which regulate their distribution.

Vegetables are regulated in their terrestrial distribution by conditions of soil, heat, moisture, light, height of situation, and various other causes; *in the waters*, by depth, heat, light, nature of bottom, and the presence of mineral and saline ingredients. Were it not for these causes, there is no reason why the tribes and genera of one region should not be identical with those of another—why the palms of India should not flourish alongside the oaks of England, the oaks of England with the pines of Norway, or these again with the dwarf birches of the arctic regions. As it is, the tropics have genera unknown to the temperate zone, and every advance poleward brings us in contact with new and peculiar species. Temperature in this case seems to be the grand regulating condition; and as this is effected by elevation, as well as by increase of latitude, we find the mountain-ranges near the equator presenting all the features of a tropical, temperate, and even arctic vegetation. Thus palms and plantains may luxuriate at their bases; then appear oranges and limes; next succeed fields of maize and wheat; and still higher, commences the series of plants peculiar to temperate regions. In temperate latitudes, though the variety of vegetation be less, similar phenomena present themselves. Besides these great climatic effects, there are others depending on soil, moisture, light, &c., which, though limited, are not less imperative. Thus, the southern slope of a hill is generally clothed with species distinct from those on the north; a limestone district presents a carpet of vegetation widely different from that of the clayey moorland: some tribes flourish in the moist valley, which would die on the open plain; some tribes thrive in the marsh, others on the dry upland; some luxuriate under the influence of the sea-spray, which would be instant destruction to others. But whilst most species are subject to these laws, there exists in the constitution of many a certain degree of elasticity which admits of their adaptation to a wider range—a beneficent arrangement, which permits man to extend through cultivation those grains and fruits upon which his subsistence so essentially depends. (For further and more minute information respecting the laws which regulate the dispersion and distribution of plants, see VEGETABLE PHYSIOLOGY.)

The animals which people the globe are subjected to somewhat similar laws of distribution. Some are strictly tropical, others confined to the temperate zone; while not a few are destined to find their subsistence wholly within the polar circles. Besides this general distribution, we find a more particular restriction to certain continents and tracts where peculiarities of soil, climate, and food seem to be the governing conditions. Thus, the elephant roams only in India, Burmah, and Africa; the ostrich in Africa; the rhea in the pampas of South America; the kangaroo in New Holland; the reindeer within the arctic circle; the polar bear amid the snows of Greenland and Labrador; and so on, as will be more minutely shewn under ZOOLOGY. Similar laws are impressed on the life of the ocean. The 'right' whale, as it is termed, of the northern hemisphere, is a different animal from that of the southern; for 'the tropical regions of the ocean are to him as a sea of fire, through which he cannot pass, and into which he never enters;' while the sperm whale delights in warm water. The herring finds its chosen habitat in the Northern Sea; the oyster clings to a peculiar bottom, at a certain depth; the cod inhabits the same banks and shoals for ages; and a few fathoms of greater or less depth would be more fatal to many species of shell-fish than the dredge of the fisherman. As on plants, so on animals, altitude exerts a very decided influence; and we do not exaggerate when we affirm that a lofty mountain-range presents a more impassable barrier to vital distribution than the widest expanse of ocean. Though presenting a close analogy in the manner of their distribution, plants and animals differ in this respect, that many tribes of the latter—birds, fishes, and mammalia—make periodical migrations of vast extent; food and proper breeding-places being the objects of their search. These migrations must not be confounded with that adaptability of constitution which fits the horse, the dog, the ox, the sheep, the pig, and other domestic animals, to be the companions and supports of man in his onward possession of the globe. The one is but a change of place in search of food, under a congenial temperature; the other amounts to a constitutional change, irrespective of climatic influence.

Man, of all animals, has the widest geographical distribution. This he enjoys not only from the greater adaptability of his constitution, but from that superior intelligence which enables him to counteract the effects of climate by clothing, houses, fire, and the storing of provisions. It may be justly affirmed, therefore, that there is no region where man may not exist and carry on the purposes of life in a higher or lower degree of civilisation. Though generally regarded as a single species of a single genus, naturalists have divided mankind into several varieties, according to their more prominent physical features; and ethnologists, extending the subject according to minor features, language, and so forth, have subdivided these varieties into branches, types, tribes, and families. That the external conditions to which man, like all other animals, is subjected, may in the course of ages have stamped the inhabitants of certain regions with certain physical characteristics, is nothing more than what may be expected; but that every little difference of dialect, every tint of skin or colour of hair, every mould of nose or contour of skull, is warrant sufficient for a new subdivision, is an absurdity not to be tolerated. An account of the principal varieties will be given in a separate sheet devoted to ETHNOLOGY.

VEGETABLE PHYSIOLOGY.

THE science which embraces the study and investigation of the vegetable kingdom, is known by the name of BOTANY, from the Greek word *Botané*, a plant. That department of the subject which explains the organisation and vital functions of plants, we call *Vegetable Physiology;* and that which recognises their arrangement into orders, tribes, genera, and species, according to their respective forms and qualities, *Systematic Botany*. The one relates to functions which are common to all vegetables, the other takes notice only of those structural peculiarities which serve to distinguish one species from another, and to enable the botanist to form these into natural and artificial groups. It is to the former of these departments that we now direct the attention of the reader.

GENERAL ECONOMY OF VEGETATION.

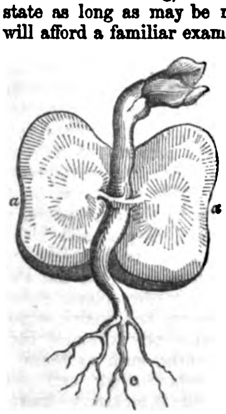
Nature and Functions of Plants.—Minerals, plants, and animals are all formed by the chemical combination of certain elementary substances. In minerals, these elements combine by the force of chemical affinity only, but in plants and animals they are held in combination by vital action. Of the nature of life, or the vital principle, science does not attempt to explain the cause, but restricts itself to a mere exposition of its phenomena. Vitality enables plants and animals to absorb and assimilate food, consisting of the elements necessary for their increase, and also to reproduce beings of their own kind; these functions are performed by means of certain organs: hence the origin of the term *organised*, which is now, however, employed to indicate the possession of vital tissues. Animals feed partly on other animals, and partly on plants; and plants feed partly on organic matter when decomposed, and partly on inorganic. Thus mineral substances, by the beautiful economy of nature, contribute towards the support of animals through the medium of vegetation, and these again, by their death and decay, return their elements to the inorganic world.

The simplest forms of life are observable in certain plants and animals, whose economy is limited to the absorption and assimilation of nutriment, and the power of reproduction; and the difference between these inferior forms is so trifling, that in them the animal and vegetable kingdoms seem to pass into each other. Thus certain tribes of animals, and some kinds of algæ, are so very nearly allied, both in appearance and habits, that they can scarcely be distinguished from each other scientifically; and indeed the same object has been occasionally classed as a plant by one naturalist, and as an animal by another. The absolute differences between plants and animals are indeed difficult to define, when they are to be applied to all plants and to all animals. Many of the infusoria of Ehrenberg, which have been described as animals, are now regarded as belonging to the vegetable kingdom; while a large number of organisms exist whose place in the system is still undetermined. In many cases, form and structure afford no decisive characters whereby we may separate the two kingdoms from each other; while phenomena usually regarded as pertaining to the animal kingdom are prevalent in the lower forms of plants, and indicate that no reliance can be placed upon their mode of life. In like manner, the chemical distinctions upon which much dependence has hitherto been placed, give way before increased knowledge; for cellulose and starch, long considered as peculiarly vegetable products, are now known to occur in animal structures. The locomotive power of many of the lower algæ is greater than that of many animal organisms; and even the spores, or seeds, of algæ of more complex organisation move about, when freed from their parent, with an activity which appears truly animal, by means of the cilia with which they are provided. When the spore finds a suitable resting-place, its movements cease; and having thus exchanged its animal-like mode of life for one of a less erratic character, it becomes developed into a beautiful alga in all respects resembling its parent. The constant recurrence of this active period in the alga's life is one of the best indications that mere power of locomotion cannot be founded upon as a proof of the animal nature of any organism. It may here be stated, however, that in the higher plants and animals, the whole plan of structure and vital phenomena are diverse in the two classes of beings. Even in the highest plants, all the processes of growth and reproduction are performed simply by cell-development; we have no circulatory and no nervous system, no power of sense or of voluntary action. The two classes, plants and animals, seem, as it were, to start from a common point at the base, the inferior forms bearing a certain similarity in structure and functions, which gradually disappears as we ascend in the scale of development.

Plants derive their food partly from the soil and partly from the air; and whatever they take must either be reduced to a liquid or to a gaseous state. The ultimate elements of which plants are composed are—carbon, oxygen, hydrogen, and nitrogen. Of these, carbon, which is a solid substance, is the principal; and as it is insoluble in water, it must be combined with oxygen, so as to form *carbonic acid gas*, before it can be taken up by plants. Oxygen is the next in abundance, and it is absorbed principally when combined with nitrogen, in the form of atmospheric air. Hydrogen is not found in a free state in the atmosphere, and therefore it can only be taken up by plants when combined with oxygen, in the form of water, or with nitrogen, as ammonia, in which last form it exists in animal manure. Nitrogen, though found in very small quantities in plants, is an important element, as it constitutes the principal ingredient in the *gluten*, which is the most nutritive part of corn and other seeds, and which is essential to the germination and nourishment of young seedling plants. Nitrogen also appears to be a principal agent in the production of colour in leaves and flowers, especially when they first expand. As oxygen is imbibed by plants in combination with all the other elements of which they are composed, it is not surprising that the plant takes up more of this gas than it requires; and, consequently, it has been furnished with a remarkable apparatus in the leaves, to enable it to decompose the carbonic acid and other gases which it has absorbed, and to part with the superfluous oxygen. Plants are thus found to improve the air by the removal of carbonic acid, which is injurious to animal life, and by the restoration of oxygen, which is favourable to it; and so to maintain a necessary equilibrium in the atmosphere, as animals are continually absorbing oxygen, and giving out carbonic acid. In hot swampy countries, however, where vegetation is extremely rapid, and the soil surcharged with decaying vegetable matter, plants absorb more carbonic acid than they want, and under certain circumstances give out the superfluity through their leaves; hence warm moist climates, such as those of some of the West India Islands, though extremely favourable to vegetation, are highly injurious to human life. Light being essential to the decomposition of

carbonic acid gas in the leaves, oxygen is not exhaled by plants during the night; but, on the contrary, a small quantity of carbonic acid gas escapes, and oxygen is absorbed. These processes have been called the *respiration of plants;* but they are very different from the respiration of animals. When the soil abounds in carbonic acid gas and in moisture, the roots of a plant must continue constantly absorbing that moisture mixed with the carbonic acid; and this carbonic acid rising to the leaves, escapes in its original state, when there is no light to decompose it. The absorption of oxygen is a chemical process, which appears to go on whenever the process of assimilation has ceased—in dead plants as well as in living ones. When leaves have ceased to act in decomposing carbonic acid, and assimilating or fixing the carbon in autumn, oxygen is absorbed so rapidly as to change their colour to some shade of red; fruit, when fully swelled, ceases to assimilate carbon, and becomes intensely acid by the absorption of oxygen; and, finally, the decay of all vegetable texture is hastened by the absorption of the same element. Thus, as the assimilation of carbon ceases during the night, oxygen is absorbed at that period in quantities that vary according to the nature of the plant; those plants which have acid or highly flavoured juices absorbing most. Baron Liebig tells us that the tasteless leaves of the American aloe (Agave), if kept in the dark twenty-four hours, absorb only 0·3 of their volume of oxygen in that time; while the leaves of the spruce fir, which contain volatile and resinous oils, absorb ten times—those of the common oak, which abound in tannin, fourteen times—and those of the balsam poplar, twenty-one times, as much. The chemical action of oxygen on vegetation is strikingly exemplified in the leaves of a species of navel-wort, which are said to be acid in the morning, tasteless at noon, and bitter at night—the acidity being caused by the accumulation of oxygen during the night, the noonday insipidity by the mixture of the oxygen with hydrogen, and the nocturnal bitter flavour by an excess of hydrogen.

Development of Vegetable Life.—This depends upon the concurrence of certain agents, the principal of which are—heat, air, moisture, light, and soil. No seed can germinate without the concurrence of the three agents of heat, air, and moisture; but in the *growth* of most plants, the agency of soil and light is also necessary. Every perfect seed contains the germ or embryo of a new plant of the same kind as the parent, and a portion of concentrated carbon and nitrogen, in the form of starch and gluten, laid up to serve as nutriment for the young plant, till its organs are sufficiently developed to enable it to seek food for itself. This nutrient matter is either contained in the tissues of the embryo itself, or laid up beside it in the seed, in the form of separate albumen. The seed is generally furnished with a hardened covering, in order to preserve it in an inert state as long as may be necessary. The common bean will afford a familiar example of the process of germination.



As soon as it is put into the ground, it is acted upon by the influence of heat and moisture, which distend its tissues, so as to burst the external integument. The agency of the air is next required to combine with the store of nutriment laid up in the seed, and to fit it for the purposes of vegetation. The first organ which expands in the embryo of a young plant is the radicle *c;* and nature has provided a small opening in the covering of a seed, towards which the point of the root is always turned, in order that it may be protruded without injuring its soft and delicate texture. The radicle takes up water and air, and transmits the liquid thus formed to the other tissues. The nutritive substances laid up in the cotyledons (*a a*) of the seed become quite changed during the process of germination. The starch, which is insoluble in water, is rendered soluble by the action of a peculiar substance called *diastase,* derived from the gluten. This substance has so powerful an effect upon the starch as to render it instantly soluble in the sap, and thus nutriment is gradually prepared for the use of the infant plant. As the sap ascends, it becomes sweet, the starch becoming changed into sugar, and this sugar, again, into woody fibre as the tip of the plant emerges into light. When the store of starch and gluten has been exhausted, the plant is able to subsist by its own assimilating powers, at the expense of the air and the soil.

Heat, though essential to germination, is injurious, unless it be combined with moisture. A high degree of dry heat will parch seeds, and destroy their vitality; hence, when they are to be kept for food, it is not unusual to dry them in an oven, to prevent them from germinating. When combined with moisture, a very high temperature is not injurious to many kinds of plants, especially those of low organisation; for example, various species of Oscillatoria inhabit the hot springs of Italy and the hot-water pools around the geysers in Iceland; while, on the other hand, certain lichens and mosses grow in the region of perpetual snow, where the temperature seldom rises to 32° Fahrenheit. Warmth is not only necessary for the germination of the seed, but also for the growth and after-development of the plant. In flowering plants the sap will not rise without a certain degree of heat; and it is well known that frost stops its current. Cold will also check the development of the flowers and fruit, and even of the leaves, and will prevent the full flavour being attained by the fruit. The secretions of plants are diminished by cold. The fruits of the walnut and the beech produce oil in the south of Europe, but not in Britain; and the leaves of the mulberry grown in this country will not afford the same quantity of caoutchouc to the silk-worm as in France and Italy.

Moisture must be combined with heat and air to render it useful to vegetation. An excess of moisture without heat, and combined with air, induces decay in seeds, instead of exciting them to germinate; and an excess of moisture is injurious even to growing plants, as it destroys the delicate tissue of the spongioles of their roots. When trees are grown in situations where they have abundance of heat and moisture, but where the roots are beyond the reach of air, they have a tendency to produce leaves instead of fruit and seeds, and all their secretions are weakened. On the other hand, too little moisture prevents the leaves and fruit from attaining their proper size and form.

Air is essential both to the germination of the seed and the development of the plant. Without oxygen from the atmosphere, the carbon laid up in the seed cannot be made available for the use of the infant plant, as carbon in its concentrated state is insoluble in water, and requires to be combined with oxygen to convert it into carbonic acid gas. In like manner, air is essential through all the processes of vegetation; no wood can be formed, no seed ripened, and no secretions produced, without abundance of carbon; and this cannot enter the plant, even from the soil, without a constant supply of oxygen from the air. The greater part of the carbon in plants is indeed derived directly from the air by the leaves, in the shape of carbonic acid gas—a minute quantity of which is always found in combination with the atmosphere.

Light is not required for the germination of seeds, but it is essential to the development of plants, as it occasions the decomposition of the carbonic acid contained in the parts exposed to its influence; without which the plant

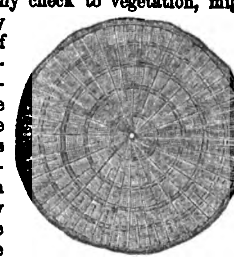
could not assimilate the carbon. Colour also appears to depend partly on light. Plants grown in darkness are of a sickly aspect, and are said to be *etiolated*, or blanched.

The soil serves not only as a bed for plants to grow in, but also contributes to their nourishment. In addition to the elements of which they are principally composed, there is always found in their substance a small quantity of inorganic matter, which differs according to the nature of the plant, and which appears to be derived solely from the soil. Plants require different kinds of inorganic food, according to their nature, and appear to possess the power of selection, as they only take the kind they need, though it may form but a very small portion of the soil in which they grow. Thus it is evident that any particular crop must in time exhaust the soil in which it grows of the requisite inorganic matters, unless they should be renewed by the addition of what are called mineral manures (see AGRICULTURE); and it is also clear that crops requiring another kind of earth may succeed in the same soil after it has become unproductive for the first kind of crop. This, according to modern doctrines, explains the necessity which is known to exist for what is called *the rotation of crops*—that is, for letting crops of a different nature succeed each other in fields and gardens. The necessity for this rotation was supposed by Decandolle and others to arise from plants poisoning the soil with the excrementitious matter which they were supposed to eject by their roots; but, while this hypothesis was believed, it appeared difficult to account for the well-known fact, that the same crops could be grown perfectly well in any soil for an indefinite number of years, provided that soil were frequently and properly manured; that is, supplied afresh with the ingredients of which it had been exhausted by the plants. As to the matter which is discharged from the roots, it is not definitely known to exercise any deleterious effect upon the same kind of crop in the manner Decandolle supposed.

Nature, when unassisted, invariably makes an effort to change the crops of plants. When a forest in North America is burnt down by accidental fires in the summer season, trees of quite a different kind spring up from long concealed seeds, in place of those which have been destroyed. When, in ordinary circumstances, one kind of plant has exhausted the soil in its neighbourhood, it pushes its roots to as great a distance as possible in quest of food, and there sends up shoots, while a new race of plants grows upon the spot which it has vacated. In these, as in a thousand other circumstances, we find that one of nature's great primary laws is that of perpetual change—an alteration from one condition and appearance to another, in endless succession and variety. In the artificial cropping of the ground, the farmer, for his own sake, is impelled to take a lesson from nature, and to study what species of plants he can most advantageously produce in succession from his fields. (See AGRICULTURE.)

Term of Vegetable Existence.—The longevity of plants differs according to their nature and the circumstances in which they are placed: thus herbaceous plants, the stems of which are succulent, not permanent and woody, are *annuals*—that grow only one season, and die as soon as they have ripened their seed—*biennials*, which generally last for two years—or *perennials*, which last for several years. Trees and shrubs, which have ligneous or woody stems, are destined to remain undecayed for years. The term *shrub* is applied to those woody plants which branch out from near the root, and seldom attain a great height; while *trees* have, generally speaking, only one stem or trunk proceeding from the root to a considerable height before it divides into branches. The length of time which trees live depends in a great measure on the situations in which they grow. If a tree which is a native of mountains be placed in a valley, it grows more rapidly, but the term of its existence is shortened, and its timber becomes softer. In like manner, if the tree of a valley be grown on a mountain, the term of its existence is lengthened, and its trunk is of slow growth and small dimensions; but it has not been ascertained that its timber is more durable on this account.

The age of trees was formerly calculated by their diameter, or by the number of concentric circles or layers in the trunk; but both these modes are now found to be fallacious. According to the first, it was supposed that if a tree attained the diameter of a foot in fifty years, fifty years should be counted for every foot it measured in diameter; and thus it was supposed that the great baobab-tree, found by Adanson on the banks of the Senegal, which measured nearly thirty feet in diameter, must have been about 6000 years old, or coeval with the world itself. It is now found, however, that the baobab, like all soft-wooded trees, grows rapidly, and attains an enormous diameter in less than a hundred years. The mode of counting by concentric circles only applies to exogenous trees, and even with them is very uncertain. A warm spring, which sets the sap early in motion, followed by weather cold enough to check vegetation, will give the appearance of two layers in one year, as the recommencement of vegetation will have the same appearance as a new layer in spring. In many trees, such as the oak, for example, a second growth often takes place after midsummer; so that even a third layer is occasionally formed in the course of six months. On the other hand, it is possible that a moist warm winter, by keeping the tree growing the whole year without any check to vegetation, might give the appearance of only one layer to the growth of two years. Notwithstanding these anomalies, practical men find counting the concentric circles of a tree the best mode which has yet been discovered of ascertaining its age, as in northern countries only one growth is made in the course of a year. The accompanying figure represents a section of an exogenous stem five years old, having the pith in the centre, a cylindrical layer for every year of the growth, and the bark on the outside.



DISTRIBUTION OF PLANTS.

The geographical arrangement of the vegetable world is influenced by conditions of soil, heat, moisture, light, altitude of situation, and various other causes; for, did they flourish independently of these conditions, then there were no reason why the vegetation of one part of the globe should differ from that of another. We know, however, that the flowers, shrubs, and trees which adorn the plains of India, are not the same with those which clothe the valleys of Britain; and that these, again, are totally different from the scanty vegetation of Iceland or Spitsbergen. Each species is, nevertheless, perfectly adapted to the conditions under which it exists, and finds in its *habitat*, or native situation, all the elements required for its growth. Obvious, however, as are the effects of these external conditions, the mode in which they operate is but imperfectly known.

In a state of domestication, however, many species exist in regions far beyond the limits of their original distribution. Our cultivated useful plants are of this kind; as, for example, the potato. This plant, which is a native of tropical America, flourishes luxuriantly, and is of the highest utility in Northern Europe; but this it does by a special adaptation. In South America, the warm climate enables it to propagate by the seed; hence in that region its tubers are small and insignificant; but in Europe, where the climate is unfavourable to the production of the plant from seed, it propagates by the tubers, which are consequently enlarged,

so as to contain a store of nutriment for the young plant, before its stem and leaves be sufficiently developed.

The habitats of plants—that is, the situations in which they naturally thrive best—are generally distinguished as follow:—*Marine*, when the plants float upon, or are immersed in, salt-water, such as sea-weeds; and *maritime*, when they grow by the sea-shore, or in places exposed to the influence of the sea-breeze. *Aquatic* is the general term for fresh-water habitats; and these may be *lacustrine*—that is, growing in lakes—*fluviatile*, in rivers—or *palustrine*, when in marshes or wet meadow-lands. Plants are also distinguished as growing in open pastures, in cultivated lands, woods, mountainous parts, and in caves, mines, and other underground excavations. The term *epiphyte* indicates that the species grows upon others, living or dead, without deriving from them the elements of nutrition; and *parasite*, that it adheres to their surface, enters their tissue, and directly extracts its nourishment. The range of habitat is that extent of the earth's surface over which a plant is distributed by nature. The terms maritime and alpine, for example, are general in their application, and refer to all plants which grow by the sea-side or on mountains; but the plants which flourish on the sea-shores of Great Britain are not the same with those on the coast of Africa; nor are these, again, identical with the maritime vegetation of Chili. The geographical range of any plant conveys a more special idea, and embraces only that particular tract over which the species extends. This range is circumscribed by conditions of temperature, light, and elevation above the sea, and does not, as might be supposed, depend very closely upon belts of longitude, by which temperature is generally indicated. Thus, nearly all the beautiful Pelargoniums and Mesembryanthemums which adorn our green-houses, are natives of a limited space near the Cape of Good Hope, as are also many of our most beautiful bulbs. The curious Stapelias, that smell so much like carrion, are found wild only in South Africa. The different kinds of Eucalyptus and Epacris are restricted to Australia. The Umbelliferous and Cruciferous plants spread across Europe and Asia; the Cacti are found in tropical America; and the Labiatæ and Caryophyllaceæ are seldom found beyond Europe. The peculiar ranges and centres of vegetation, as they are termed, cannot be sufficiently understood, however, without a knowledge of the different tribes and classes of plants, the consideration of which forms the subject of next paper—SYSTEMATIC BOTANY.

Soil exercises less influence on the distribution of plants than is usually ascribed to it, though there can be no doubt that on its power of absorbing and retaining heat and moisture much of the luxurious growth of vegetables depends. They will grow to some degree in almost any soil, as the bulkier ingredients—clay, lime, and sand—always predominate; but a proper proportion of these earths is necessary to perfect vegetation, and many plants will not continue healthy and propagate unless supplied with other elements, such as potash, soda, and various metallic salts. For this reason, the natural vegetation of a limestone country differs from that of a retentive clay; while the plants which cover all sandy downs are totally different in kind and character from those of the alluvial valley. Moisture, which is indispensable to the existence of vegetation, also exercises great influence in its natural distribution. The plant which roots in the parched sand is furnished with leaf-organs to absorb moisture from the atmosphere, and retain it; while in a wet situation these organs would become diseased, and rot away; so, in like manner, a marsh-plant, whose spongioles are its main organs of sustenance, would perish were it removed to an arid soil. The organic structure of such plants forms a limit to their distribution; and the same may be said of the Salicornia, Lepigonum, &c., which live only when exposed to the salt spray of the ocean.

Heat and light are perhaps the most manifest agents in the distribution of vegetable life. The luxurious growth of the tropical jungle is the direct result of warmth and moisture, just as the barrenness of Nova Zembla is the effect of piercing cold; yet both situations are inhabited by plants which enjoy the conditions peculiar to their existence. No conditions of mere soil, or light, or moisture, could make the palms, tree-ferns, and jungle-flowers of India flourish in Great Britain; so neither would our oaks or pines flourish in Iceland, unless we could provide for them that temperature and seasonal influence necessary to their healthy existence. Light, though it acts most powerfully on the colours and blossoms of plants, is in some measure an element in their geographical arrangement. The northern side of a hill may sometimes be as green, but it never will be so flowery as the southern exposure; and the attentive observer may detect new tribes on either side almost as soon as he has passed the summit. The more free the exposure, the more readily will most plants also blossom, and yield a rich fruit. So well is this understood in the grape-countries on the Rhine, that the right bank of that river, which faces the sun, is reckoned to be much more valuable than the left, and commands a higher price for its wines.

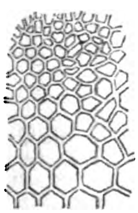
Altitude, or elevation above the ordinary sea-level, also exerts an obvious influence on the distribution of vegetable life: it is equivalent to removal from a tropical to a temperate region, or from temperate latitudes to the arctic circle. For every hundred feet of ascent, there is a proportional fall of the thermometer; so that, at the height of 5000 feet in the latitude of Britain, and 16,000 at the equator, we arrive at the region of perpetual snow; in other words, to heights as destitute of vegetation as the frozen zone. This intimate relation between altitude and decrease of temperature accounts for the fact, why the base of a mountain may be clothed with the vegetation of tropical India, the sides with that of temperate England, and the summit with the mosses and lichens of icy Labrador. 'We may begin the ascent of the Alps, for instance, in the midst of warm vineyards, and pass through a succession of oaks, sweet chestnuts, and beeches, till we gain the elevation of the more hardy pines and stunted birches, and tread on pastures fringed by borders of perpetual snow. At the elevation of 1950 feet, the vine disappears; and at 1000 feet higher, the sweet chestnuts cease to thrive; 1000 feet further, and the oak is unable to maintain itself; the birch ceases to grow at an elevation of 4680; and the spruce fir at the height of 5900 feet, beyond which no tree appears. The Rhododendron ferrugineum then covers immense tracts to the height of 7800 feet; and the herbaceous willow creeps 200 or 300 feet higher, accompanied by a few saxifrages, gentians, and grasses; while lichens and mosses struggle up to the imperishable barrier of eternal snow.'

The circumstances which facilitate the dispersion or migration of plants, are not unconnected with the causes which limit their geographical distribution. Many seeds drop from the parent stalk, spring up into new series of stems, which in turn give birth to another race of seeds, and these again to another circle of vegetation. Thus, any species of plant would spread from a common centre till arrested by the influences which limit its range of habitat; and this mode of dispersion no doubt occasionally occurs. In most plants, however, the seeds are small and light, and easily borne about by the winds: some are downy, and furnished with wings, while others are ejected from their carpels with considerable force. All these appendages and peculiarities are evidently intended to facilitate their dispersion, which is further assisted by rivers, lakes, and tidal currents, by the wool of animals, the droppings of birds, and the economical pursuits of man, whether accidental or intentional. The seeds are arrested in their progression by various causes: some are furnished with barbs and

hooks, which lay hold of objects; others become entangled amid herbage, the mud of rivers, or the softened soil of winter; while many, towards spring, are acted upon so as to emit an adhesive substance, or their fleshy pericarps melt down into the soil, carrying the embryo along with them.

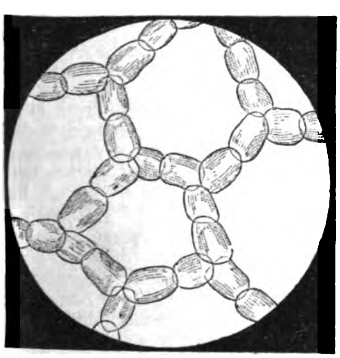
STRUCTURE OF PLANTS.

In order to explain the varied phenomena of plant-life, we must revert to the elementary tissues of which the various compound organs are composed. It is in these tissues that the processes of growth and multiplication, of individual development and of reproduction, can alone be accurately traced. Vegetable Histology limits itself to such investigations. If we cut a thin slice from the leaf or stem of a plant, and place it under the object-glass of a microscope, we shall find it to present the general appearance of a web or tissue, more or less of a honeycomb form, as represented in the wood-cut (*a*). If more carefully examined, it will be found that the apparent meshes of the net-work are not hollow spaces or perforations in a homogeneous mass or membrane, but that each has its own envelope, is, in fact, a minute bladder or vesicle, or elongated tube, as the case may be; and that the whole mass of tissue is formed by the aggregation of such vesicular or tubular bodies held together by means of an imperceptible layer of intercellular matter, which causes the contiguous cell-membranes to cohere. In the tissues of plants there is an infinite variety, both as regards the form and arrangement of their elementary bodies, the cells; but all may be reduced to three distinct types of structure, to one or other of which every modification can be referred. These are distinguished as the *cellular*, *woody*, and *vascular* tissues.

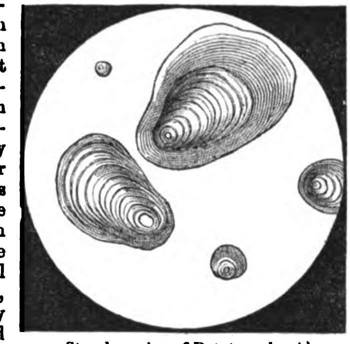


a, Cellular tissue.

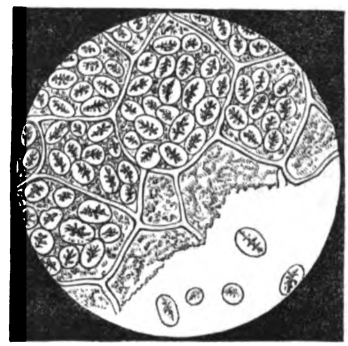
Cellular tissue may be said, in general terms, to form the soft and succulent parts of plants—as, for example, the pith of trees, the delicate central tissue of Papyrus, shewn in the adjoining figure (*b*), and the soft parts of our esculent vegetables and fruits. It is composed of minute bladders or vesicles, which are called *cells;* these are seldom so large as to be visible to the naked eye, but are readily seen under a compound microscope. They usually consist of a pellucid membrane, and are filled with fluid, in which float the cell-contents. These consist principally of the starch and chlorophyll granules; the latter, which are of a green colour, serving to give the usual green hue to vegetation. Starch is a very abundant substance in plant-cells, serving purposes of nutrition, and may be readily seen by placing under the microscope a thin slice of potato upon which a drop of tincture of iodine has fallen; this induces a beautiful blue colour in the starch-granule, and is a constant test for the occurrence of starch. Starch usually occurs in the form of minute grains, many of which are contained in each cell. Their form is often constant and characteristic in certain plants—for example, the very minute angular starch-granules of rice are quite different from those of the other cereal grains, which, again, are easily distinguished from those of the potato, shewn in the above figure (*c*); while those of leguminous plants have a somewhat common character (*d*). The peculiarities of starch-granules have been successfully employed in detecting adulterations of food and drugs, and for other purposes of practical utility.



b, Papyrus: pith-like tissue, composed of cells arranged in form of a net-work, so as to leave large intercellular spaces (*ad nat.*).

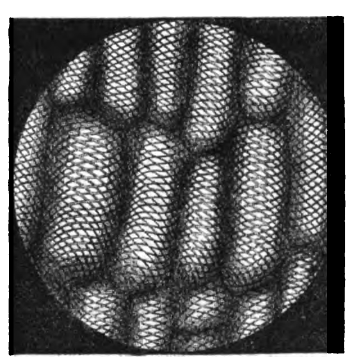


c, Starch-grains of Potato (*ad nat.*).



d, Lentil: cells of seed containing Starch-grains (*ad nat.*).

Instead of holding these cell-contents, and consisting itself of a pellucid membrane, the cell in many cases displays a thickened opaque wall and an empty cavity within. This arises from the deposit of woody matter on the interior surface of the cell-wall, which is seen in the hard stone of the cherry and in the shell of the coco-nut, both of which consist of cellular tissue equally with the softest parts of their respective fruits, and owe their solidity to the indurated woody matter. Instead of having the whole inner surface of the cell covered in this way, the deposited matter may be so arranged as to cover certain parts only: it is often deposited in the form of rings or spiral coils; and in the latter case gives rise to the beautiful spiral cells seen in the roots of epiphytal orchids and in the leaves of bog-mosses—the former are represented in the above drawing (*e*).



e, Spiral tissue from the root of an Epiphytal Orchid (*ad nat.*).

With respect to their general form, cells are exceedingly variable, and are usually greatly modified according to the position in the plant which they occupy. They very commonly present the hexagonal appearance represented in the wood-cut (*a*); but in the bark and young stems, as well as in roots and other parts, they

often assume an oblong form (fig. *e*); sometimes resembling the bricks of a wall set on end, and thus indicating the manner in which plant-structure is built up, as it were, by separate cells cemented together.

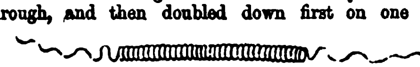
The rounded or spherical form may be regarded as the normal form of the cell, the two modifications to which we have alluded arising from the pressure of spherical or oval cells in contiguity, or special modifications intended to fit them for their place in the structure. In many cases, however, we find cells of a very different form, whose modifications obviously arise from certain special functions which they are designed to perform. The pith-like substance of the rush, used as wick for lamps, consists of cells of a most beautiful stellate form; the free cells or spores of certain algæ are covered with cilia, which give them locomotive power; the cells of hairs are elongated, and often much branched; and the cells of unicellular algæ, such as the Desmideæ and Diatomaceæ, often display the most exquisite symmetry, both in outline and in the elaborate sculpture of their surface. The cotton fibre, which is a cell in peculiar condition, presents the form of a flat twisted band with a thickened margin, a character which is retained by the fibre after it is dressed, spun, and woven into cloth, and even after that cloth has been worn to rags, reduced to pulp, and remanufactured into paper.

In the pulp of leaves and fruit, and in the cellular tissue of the bark, there are frequently cavities found among the cells, which are of several kinds. Those called *receptacles of secretion* are formed for the reception of the oils and other fluids secreted by plants; as, for example, the fragrant oil in the myrtle and the orange, and the turpentine in the pine and fir tribe. Other similar cavities, called *air-cells*, contain oxygen nearly in a pure state, and are called *intercellular spaces*. All these cavities have no distinct membrane to enclose them, but are surrounded by what may be called a wall of cells, which form part of the cellular tissue. The shape and size of these cavities vary exceedingly; the receptacles of secretion, and the air-cells, are often of very great size, and seldom so small as to be invisible to the naked eye: if the stem of the common hippuris or mare's-tail, or the leaf-stalk of a water-lily, be cut across, a beautiful arrangement of these intercellular spaces will be displayed, and the manner in which they are formed by the peculiar arrangement of the plant's cells is shewn in wood-cut *b* (page 69).

Cellular tissue readily decays when the parts composed of it fall from the tree. The carbon it contains is liberated so soon as the vital force by which it was retained has fled, and escapes with the oxygen in the form of carbonic acid gas; whilst the hydrogen, which then forms its principal remaining element, attracts fresh oxygen from the atmosphere, and becoming thus changed into water, rapidly melts away, leaving the inorganic portion to mix with the soil. In leaves, the pulpy parts disappear first, leaving behind the outer cuticle and the nerves or veins, which are of firmer texture; the latter, indeed, being composed principally of woody fibre, the tubes of which have been filled with earthy matter during the process of vegetation, decay very slowly. Those parts of a plant which nature seems to have intended not to be of long duration—such as the fleshy parts of the leaves, the flowers, and the fruit—are composed entirely of cellular tissue of loose texture.

Woody tissue.—It is a familiar fact that the stems of trees and of flowering-plants in general possess a tenacity not found in the leaves and flowers. This is mainly due to the presence of woody tissue, which consists of minute spindle-shaped tubes lying closely together, and overlapping each other at the ends. The strength of these tubes is mainly due to the deposit of woody matter on their inner surface. The value of many plants employed in the arts depends upon the abundance of this tissue: when separated from the softer tissues of the stem and leaves by maceration, it forms the fibre of flax, hemp, China-grass, and other textile substances well known in commerce. In cone-bearing plants, such as the common pine, the woody tissue is very peculiar, each tube exhibiting a series of round discs with a central dot. By carefully studying the peculiarities in such tissues, the sources of unknown timbers may often be determined. In most pines there is a single row of discs on each tube, while in others a double row of opposite discs is observed. In the Araucarias of the southern hemisphere, the discs are angular, and are arranged alternately in several rows; and in the yew and allied plants, the tube has beautiful spiral markings as well as minute discs. Such characters are invaluable to the student of vegetable palæontology.

Vascular tissue has been divided by modern botanists into three kinds—namely, *vascular proper*, *pitted*, and *laticiferous*. Vascular tissue, consists of cylindrical tubes of great delicacy and thinness, called *spiral vessels* and *ducts*. *Spiral vessels* are so called because they contain delicate fibres coiled round in a spiral manner. They are of a light elastic nature, and their fibres, though coiled up naturally like a cork-screw (see fig.), may be unrolled to a considerable extent. If a leaf-stalk of a geranium or strawberry be cut half through, and then doubled down first on one side,



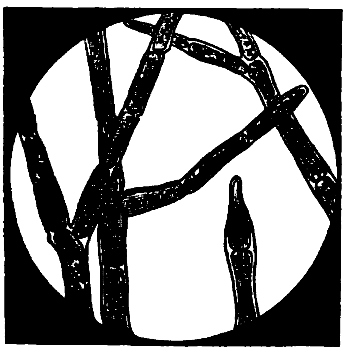
Spiral Vessel.

and then on the other, and the two pieces be then carefully and gently drawn asunder, the transparent membrane will break, and the spirals will unrol so as to appear, when seen with the naked eye, like fine hairs between the two portions of the leaf. Spiral vessels prevail in leaves and flowers, and are found, though more sparingly, in the young greenwood of trees and shrubs; but rarely in the old solid wood and in the roots or in the bark. They are few in coniferous trees; but abundant in palms and their allies. In ferns and the club-mosses they occur occasionally, but are usually replaced by a peculiar kind of vascular tissue, called the *scalariform* tissue, from the ladder-like markings on its angular vessels; the other cryptogamous or flowerless plants are entirely without vascular tissue. These vessels are sometimes called *air-vessels*, because their slender spiral tubes are always found filled with air.

Pitted tissue, sometimes called *dotted ducts*, consists of tubes which, when viewed by transmitted light, appear full of holes, from the numerous dots in the lining of their membrane. The mouths of these tubes are very conspicuous in the wood of the rattan when cut across; they are also to be seen in sections of the oak and the vine; and indeed in most other kinds of wood, as well as in the stems of herbaceous plants. The dotted ducts are larger than the vessels of the other tissues, and are distinctly visible in many kinds of wood, even to the naked eye. Botanists consider them as belonging to cellular tissue, and as consisting only of elongated cells placed end to end, and opening into each other so as to form a kind of tube. Laticiferous tissue consists of tubes which are distinguished from all other kinds of tissue by being branched. They are filled with a mucilaginous fluid called the *latex*, which is always in motion while it remains in the vessels. This milky fluid abounds in the India-rubber and gutta-percha plants, and is seen to exude in abundance from the dandelion when its leaves or stalks are wounded. This fluid, in many plants, contains a large quantity of caoutchouc; it is bland and nutritious in the cow-tree of the Caracas, but in many other plants narcotic and acrid.

Multifarious as are the modifications of the tissues of plants, and the cells and vessels of which they are composed, all have a common origin, all are modifications of the *cell*. The plant begins its existence as a cell, and its whole course of development may be said to be the

evolution of cells. The process of cell-development, or cytogenesis, thus explains the whole phenomena of plant growth and reproduction. To the investigation of this subject, therefore, the attention of vegetable histologists has of late years been specially directed, and the results have appeared in the form of certain theories which have given rise to much angry discussion. It is only needful here to indicate the modes in which cells appear to be usually produced, for no single theory appears to be applicable to all known phenomena. The two principal methods are by free-cell formation and fissiparous, or merismatic, division. By the first, the new cell originates in the protoplasmic fluid contained in a pre-existing one; a nucleus may be present, which forms the centre of vital action, and around which a protoplasmic membrane is formed, which ultimately becomes covered with a coating of cellulose, forming the proper cell-membrane. But a nucleus is not essential to this mode of cell-formation, the protoplasm being the active agent. It will be seen that in this way an old cell becomes developed into two or more (contained) new ones, which increase in size equal to their parent; and in this way the growth of many parts of plants is accomplished. But there is still another mode of cell-development, well seen in a confervoid water-weed (shewn in the adjoining figure) which has of late years choked up Duddingston Loch, near Edinburgh. This consists in cell-division; the inner layer (primordial utricle) of a previously formed cell becomes folded inwards in the middle, so as to divide off the cell into two compartments; a cellulose wall is secreted upon the folded utricle, and thus the division is complete, two cells being formed where only one existed before. In many cases, the development of cells goes on with amazing rapidity. In damp weather, the gigantic puff-ball will grow up in a single night from a mere point to the size of a large gourd, forming on an average not fewer than 20,000 new cells per minute.



Cladophora Fracta, a filamentous fresh-water Alga, in which cell-division is well seen (*ad nat.*).

GENERAL INTEGUMENT AND ITS APPENDAGES.

Submerged plants have the cells of their leaf-tissue directly exposed to the action of the surrounding water; but land-plants usually have all their organs invested in an epidermis or skin, which regulates transpiration, and prevents their tissues becoming dried up. The surface of this epidermis, again, is covered by a very thin structureless layer, called the cuticle. The epidermis is composed of a kind of cellular tissue; but the cells are pressed closely together, and flattened, and they are often filled with air instead of water. The use of the epidermis is to retain a sufficiency of moisture in plants; for should the delicate membrane of which the cells of their tissue are composed become so dry as to lose its elasticity, the different organs would be unable to perform their proper functions. On this account, its thickness is curiously adapted to the conditions under which a plant grows. Plants of very hot countries are supplied with three or even four layers of dense external tissue, in order that the moisture may be retained, notwithstanding the excessive heat and dryness of the climate. But it is necessary that the tissues of plants should not be shut out from the free action of the atmosphere, whence a large proportion of their food is derived. They are therefore provided with peculiar breathing-pores, or stomata, in the epidermis, by which air enters, and from which fluid transpires. Those plants which have numerous pores, or stomata, in their epidermis, require watering oftener than others, and are more easily affected by the heat of the sun. Some curious calculations have been made of the number of these stomata on a given surface, in different plants, the general result of which is that their size, number, and arrangement are strictly in accordance with the requirements of the plant and the function which they perform. In mosses, where the leaves usually consist of a single layer of cells, stomata are confined to the fleshy base of the fruit; but in flowering-plants they chiefly occur on the under surface of the leaf; and this is especially the case in many evergreen shrubs, which are thereby enabled to benefit by the moist exhalations from the soil and herbage beneath, without suffering from a scorching sun. This law is reversed where the habits of the plant require such an adaptation. Water-lilies and other plants whose leaves float on the surface of the water or lie flat on the soil, have no stomata on their under surface, but are supplied with an increased number on their upper surface, which alone is exposed to the action of the atmosphere. The following calculation of the number of stomata in the leaf of the royal water-lily, will serve to indicate the extremely minute size of these bodies and the great numbers of them required by plants: each stomate measures the $\frac{1}{360}$th part of an inch in diameter; one square inch of surface contains 139,843 stomata; so that one ordinary sized leaf of this plant, with a surface of 1850·08 square inches, contains upwards of twenty-five millions of stomata (25,720,937).

In the oleander and in the proteaceous plants of New Holland, the stomata are not equally disposed over the surface, but occur in groups, which are protected by incurved hairs from the excessive action of drought—a remarkable instance of provision for special circumstances of climate.

Hairs are minute prolongations from the epidermis, and are found upon almost every part of plants. Sometimes they cover the whole of the leaf, and at others they are only found on one surface. They are described in general terms as downy, silky, hirsute, bristly, ciliate, &c., according to their aspect and mode of arrangement. The use of hairs is partly to protect the surface of the leaf from the heat of the sun and from drying winds, and partly to collect moisture from the atmosphere. It is known that plants take in nourishment from the atmosphere as well as from the soil; and it is supposed that part of this nourishment is absorbed through the hairs. The hairs of plants are exceedingly variable in size and form, and are either unicellular or multicellular—consisting of one or of many cells. In either case, they may be simple or branched. There are branched unicellular hairs in Cruciferæ, and beautiful stellate hairs in many plants; the latter occur even in the internal cavities—intercellular spaces—of aquatic plants. The sting of the nettle is a beautiful modification of the hair, being a conical tube with a basal bulb, filled with irritant fluid, which shews singular movements under the microscope. The tube is sharp-pointed, and surmounted by a little curved knob; when the plant comes in contact with the hand, or any other body, this knob is knocked off; the sharp point which it protected now penetrates the skin; and the pressure upon the conical sting causes the irritant fluid which it contains to be poured out into the wound. The whole phenomenon is strikingly similar to the mode of action of the animal sting.

Glands.—Although it has been repeatedly stated, in recent works on physiology, that there is no true process of secretion in plants analogous to that of animals, still the latest researches seem to indicate that such a process does exist, and that it is performed by special organs—usually modifications of the epidermis itself or of its

appendages. Thus, in the Cinchonas of South America, we have conical glands, which pour out a gum-resinous matter on their free surface, which is employed by the Peruvians—under name of Oil of Mary—as an external application in various maladies; and the same kind of glands are now found in the bedstraws of our hedgerows. In many monocotyledonous plants large follicular glands of a complex structure have been described, which are probably connected with reproductive phenomena. The honey of many flowers also appears to be a true secretion, poured out upon a free surface of the tissue by special cells, which are not analogous to the fat-cells of animals, to which the so-called vegetable secretions have been likened.

Besides the above-mentioned organs, there are prickles, thorns, and spines. *Prickles* may be called hardened hairs, as they are merely indurated expansions of the epidermis, without any woody fibre; and they may be detached from the branch which bears them without laceration. *Thorns* differ from prickles, in being formed partly of woody fibre; and they cannot be detached from the branch which bears them without lacerating its vessels. They have their origin in buds, and are the result of an arrestment of development, being formed instead of leaves and branches. *Spines* resemble thorns in every respect, except in being found on the leaves and stems of herbaceous plants; while thorns only grow on the trunk and branches of woody plants. When spines grow on leaves, they are always found on the veins which are extensions of the woody fibre.

ORGANS OF NUTRITION.

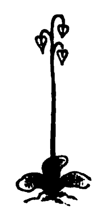
The organs of nutrition are the root, the stem and its branches, and the leaves; and of these organs, the root and the leaves, or some modification of them, exist in every flowering-plant, as the vital functions cannot be carried on without them.

The root (*radix* in Latin) is commonly defined to be that part of a plant which attaches itself to the soil where it grows, or to the substance on which it feeds, and is the principal organ of nutrition. Exceptions to this definition occur, as in the case of some vegetables which grow floating loosely in water, as duck-weed, as well as in the case of others having no root at all. As the nourishment of a plant is derived from the earth, the root is that part which grows in an opposite direction to the stem, and is buried in the ground. It is, in fact, the descending axis. The more common form is the fibrous root as seen in grasses, the fibres being terminated by spongioles, which are the absorbent points. But the main root is often thickened into a tap-root, giving off secondary fibres—globe-shaped, in the turnip—conical, or tapering gradually from the collar to the attenuated fibre, in the carrot—fusiform, or tapering at both ends, in the radish: this latter may be abrupt, where the lower end appears as if cut off, which is exemplified in the devil's bit scabious. In the dahlia, the roots branch off in a fasciculate manner; while in the orchis they are tuberous, being in the form of globe-shaped bodies filled with starchy matter. The so-called tuberous roots of the potato are considered by botanists as merely underground stems, from the circumstance of their having eyes or buds from which branches will spring.

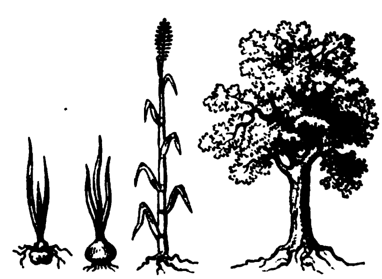
The crown, collar, or life-knot, as it is variously called, is that part which lies between the stem and the root. It is the most essential portion of the whole; for if it be removed, or seriously injured, the plant will inevitably die; whilst the small fibres or rootlets, although an essential part of a plant, may be destroyed at pleasure, so long as the crown remains, for it readily reproduces them. When it is of a slender make, it dries up as the seeds ripen, and the plant soon dies, as the poppy, mignonette, and other annuals.

Roots have a remarkable tendency to grow downwards, or in the direction of the earth's centre; and from experiments, it seems not unlikely that this tendency is to some extent an effect of gravitation. The precise direction, however, is very much influenced by the condition of the soil. Both root and rootlets extend as if in quest of food, and will penetrate sidewise or obliquely to great distances. When plants are by any means prevented from fructifying by seeds, they almost invariably increase by extending their roots or creeping-stems, from distant points of which new plants will spring up. These thus perform the functions of stems; and though the two differ in many respects, yet there are cases where it becomes difficult to distinguish between them. Some species of palms send down aërial roots for the purpose of strengthening their stems, and the same are seen very remarkably in the screw-pines. Many herbaceous plants send out roots in a similar manner when they are earthed up; and trees which grow in unnatural situations, as on a wall or bare rock, send down roots in quest of soil and moisture, which afterwards take the appearance of stems. The willow, maple, gooseberry, and some other plants, may have their roots converted into stems by reversing the plants, and burying the tips of the shoots in the earth, so as to leave the roots in the air. In this case, the branches will soon send out fibrous roots from the joints which have been buried in the earth, and the fibrous part of the old roots withering, the roots themselves will gradually assume the character of branches.

The Stem.—When a plant shews itself above the ground, it evidently manifests a strong tendency to the light. Light, in fact, is essential in bringing it to maturity, and in giving the green colour to its leaves. The stem, with a few exceptions, is always above ground. It is divided from the root by the part called the crown or collar. The space between the collar and the first branch is termed the bole or trunk. The stem of grasses, corn, and reeds, receives the name of culm; the stem of such flowers as the primrose, dodecatheon (see fig.), and the daisy, is undeveloped; hence they are called stemless (acaulescent); the stalk upon which the flowers are borne being termed the scape, or flower-stalk; the running-stem, as in the strawberry and cinquefoil, is termed a runner; a shorter runner that does not root, as in the house-leek, is termed an offset; and a small stem proceeding laterally from a root or stool, a sucker.



The stem, it will be observed, assumes many forms and characters as to bulk, structure, position, place, and



1. 2. 3. 4.

duration. It appears as a corm (*Gladiolus*, 1); a bulb (the onion, 2); a culm (*Arundo*, 3); or as a woody trunk (the oak, 4). When a trunk bears permanent or perennial branches, the plant is termed a tree; when permanent branches arise, not from a distinct trunk, but from near the root, the plant is termed a shrub; and when the whole stem is not woody, and dies down every year, at least as far as the crown of the root, the plant is termed an herb. Trunks which increase by successive layers of new wood on the outside of the old, as the ash and beech, are termed *exogenous;* those which increase by the addition of fibrous matter in the centre, as the

palms, are styled *endogenous;* and those which do not sensibly increase in thickness, and are formed by the adhesion of the leaf-stalks as they spring from the growing point, as the tree-ferns, are said to be *acrogenous.*

Buds, which have various forms, but are generally oval or roundish, consist of the young shoots either of leaf, flower, or twig, and proceed from what is called the axil of a leaf. They are usually formed either early in summer or in autumn, and are so contrived as to preserve from injury the delicate structure within. The outside is composed of tough scales, which are frequently covered with a gummy resin; and they are internally protected by a downy substance interposed between the leaves.

Linnæus applied the term *hybernacula* to leaf-buds, being the 'winter-quarters' of the young branch. With respect to the manner in which the leaves are arranged and folded in the bud, which is termed *vernation,* they may be simply placed in apposition, as in the misletoe; plaited, as in the palm and birch; doubled, as in the rose and oak; embracing, as in the iris and the sage; double embracing, as in valerian, teasel; rolled inwards, as in grasses; rolled outwards, as in rosemary, primrose, &c.; rolled lengthwise, breadthwise, rolled from the tip to the base, or wrapped round the stalk.

Leaves.—Leaves are the grand ornament of plants, and from their number, position, and delicacy of organisation, they are designed to effect an important office in the vegetable economy. Springing from the branches, and exposed in profusion to the atmosphere, they perform the functions of a breathing-apparatus analogous to that of the lungs or gills of animals. A similar purpose at least is designed; for the sap of plants, like the blood of animals, requires to be exposed to the atmospheric influence, in order that it may be suitable for nutrition. This purpose is accomplished by the agency of the leaves, to which the sap, on rising from the roots through the stem and branches, is propelled or attracted, and there both air and light exercise their beneficial influences. Leaves are thus indispensable to the growth of plants, and care should be taken not to injure them; for defoliation, either naturally or by art or accident, instantly arrests the growth, and the failure or diminished expansion of foliage is a certain sign of debility.

A leaf consists generally of two parts—the petiole,

or leaf-stalk; and the lamina, or that part which is broad and thin. Sometimes, however, as in the rose tribe, stipules (*ss*) are attached to the base of the petiole. The leaf-stalk (*a*) is that part which connects the leaf with the branch, and at the base will be found slightly hollowed, in which a bud rests. Sometimes the leaf-stalk is wanting, as in the sow-thistle and catch-fly, and in this case the leaf is said to be sessile, or sitting. The lamina, or broad part of the leaf (*b*), is frequently of a different colour on the under side. This is exemplified in the common silver-weed (*Potentilla anserina*), the leaves of which are hoary on the lower side and green on the upper. Leaves are either *deciduous*—falling in autumn—or *evergreen,* lasting till the following season. Their forms are exceedingly varied—being *simple* or *compound;* and these again are distinguished as oval, lanceolate, hastate, sagittate, pinnate, cordate, &c.

An important character is afforded by the *venation* of leaves—that is, the arrangement of what are called their veins. In exogenous plants—as our timber-trees, for example—the leaf is furnished with a strong midrib, from which secondary veins diverge, at regular distances; and these again branch off into still smaller tertiary veins, whose ramifications form a reticulation over the surface of the leaf. In endogenous plants, on the other hand—as common plantain, corn, and lilies—there is usually no distinct midrib, but several primary veins, which originate in the base of the leaf, and proceed to its apex, being parallel throughout. In many tropical endogens, however, we have a rather more complex form of parallel venation. In these cases, there is a distinct midrib, from which secondary parallel veins diverge on either half of the lamina.

The veins of leaves consist of woody tissue, accompanied by spiral vessels, the interspaces being filled up with the softer parenchyma, or cellular tissue. By maceration, the latter may be made to disappear, so as to leave merely the veins in form of a skeleton-leaf. In aquatic plants, there is a strong tendency to non-development of the parenchyma; thus, in the aquatic ranunculus, the submerged leaves consist merely of veins, while the floating ones are entire; but the most remarkable instance of this occurs in the *Ouvirandra fenestralis,* a plant of recent introduction to Kew Gardens, whose leaves are entirely destitute of parenchyma, being, in fact, beautiful lattice-like skeleton-leaves. The leaves of the royal water-lily are perforated with minute holes at regular intervals; and a view has recently been brought forward to connect this feature of structure with that seen in Ouvirandra, being a beginning, as it were, of a reduction of parenchyma, which is excessive in the latter plant. This is illustrated by the fact, that in the Ouvirandra, an occasional intercostal space *is* filled up with parenchyma, but not entirely, a round opening being left in the centre.

With regard to the manner in which leaves project from the branches, and their distribution over the woody cylinder to which they are attached, every possible variety may be observed. They may be opposite—that is, two leaves growing on either side of the branch, the one directly opposite to the other; alternate, when one leaf springs out on one side of the branch, and another on the opposite side, a little above it, and so on; whorled, or *verticillate,* when a number of leaves grow round the stem from a common knot or joint, as in the bed-straw. The distribution of alternate and opposite, however, is not regular; for in some instances it will be found that the leaves on the lower part of the stem are alternate, whilst those on the upper are opposite.

There are many plants which have few or no leaves, but whose stems are much dilated, presenting a large superficies of parenchymatous exterior to the air and light. It may be remarked that such plants as the common garden rhubarb, which require much moisture, are provided with very broad leaves, which, by their umbrageous character, preserve the soil from being parched.

Green is the most general colour of leaves, but some are red, or purple, or yellow; some appear nearly white, in consequence of being clothed with short woolly or silky hair. Leaves are often variegated in consequence of the non-development of chlorophyll in the cells

of certain parts. They differ much in substance and structure: some are immensely thick and fleshy, as those of the genus aloe; others remarkably thin, as those of the beech. The texture of the surface is also very dissimilar: some are rough, prickly, and wrinkled; others smooth and glossy.

ORGANS OF REPRODUCTION.

The organs of reproduction are the flower, fruit, and seeds; and these, or some modification of them, exist in every perfect *Phanerogamous* or flowering-plant.

Flower.—A flower consists of several distinct parts—the calyx, corolla, stamens, and pistil. A flower is essentially constituted by the presence of the two last, which are the sexual organs. When there is only one of these present, the plant is termed unisexual; but more commonly these organs are both present in the same flower, which is in this case termed hermaphrodite. In some instances, although the same plant bears both male and female organs, it is not hermaphrodite, as these organs occur in different flowers; in others, again, the male and female flowers exist only on different plants. Lastly, male, female, and hermaphrodite flowers are sometimes found mingled together, either on the same or on different plants. Sometimes the male or female organs alone, protected by a small scale, constitute the flower; but in general they are surrounded and protected by the corolla and calyx, which are called the floral envelopes. All these are commonly borne on a stalk called the peduncle (from *pes*, *pedis*, a foot), which, expanding at its extremity, forms the receptacle, or torus, as it has been called, upon which the whole of the parts

aa, anthers; *d*, filament; *b*, stigma, or summit of pistil; *e*, style; *c*, ovary, or seed-vessel; *f*, peduncle; *g*, calyx; *h*, corolla.

above mentioned are supported. What is called the berry in strawberries appears to be nothing more than the receptacle bearing the carpels on its surface.

The *calyx* is the external leafy envelope surrounding the corolla, and in which the latter rests as in a cup. Sometimes it is entire, but more frequently it is divided into segments (*sepals*), which are more or less separated from each other. It is most commonly green, but in some flowers it is highly coloured, and with difficulty to be distinguished from the corolla.

The *corolla* is the conspicuous highly coloured part of the flower or blossom, and consists of several divisions or leafy parts called *petals*, which are articulated at the base, and consequently fall off at the earliest manifestations of maturity or decay. The extensive variety of tints in the flowering part of plants is remarkable. The lower part of the single petal of a corolla is called the claw, corresponding to the stalk of the leaf; and the broad part is called the limb. The corolla is frequently furnished with certain secreting organs, attached to the throat or the base of the petals, called nectaries.

Stamens.—Within the beautiful corolla are observed several small filaments, arranged in a circle around the central parts, and bearing on their summit little oblong bodies; which are usually apparently covered with particles of a fine coloured matter like dust. These are the male parts of reproduction, the stamens, which are always next to the petals—that is, between their base and the base of the seed-organ. It is upon the number and arrangement of the stamens that systematic botanical arrangements of an artificial character have principally been founded. The following are a few characteristics of the number, length, position, direction, &c., of the stamens. The number of stamens in each flower varies from one to twenty, or more. In length they are equal or unequal, and this disproportion is sometimes symmetrical, sometimes not. In position, they may be opposed to the divisions of the petals, or they may alternate with them, which is their normal condition. Sometimes they protrude beyond the corolla, at other times they are wholly included within it. Their direction may be erect, pendent, or horizontal, and their summit is variously inclined to or reflected from the centre of the flower. The filament which supports the anther is most commonly straight and filiform; sometimes, however, it is otherwise. It varies from being as small as a hair, to be large and flat like a petal, and its summit is either pointed or obtuse. On the summit is that essential part the *anther*, which is generally formed of two small membranous sacs, attached immediately to each other, or united by an intermediate connecting body. In form, anthers are subject to great variety, and, like the filaments, they sometimes cohere so as to form a sort of tube.

The pollen contained in the anthers consists of numerous small bodies, which possess in different plants a very different figure, size, and colour. The number of these in a cell, which is very small, sometimes amounts to many thousands. In some flowers, the pollen-grains are transparent; in others, they are of a white, purple, blue, or brown, and more frequently of a yellow colour; and they often display exquisite markings on their surface, which enables the pollen of certain orders to be identified under the microscope. When a grain of pollen is dropped into water, it swells, and sometimes bursts, emitting a minute quantity of granular matter, which is supposed to be the portion more essential to fecundation.

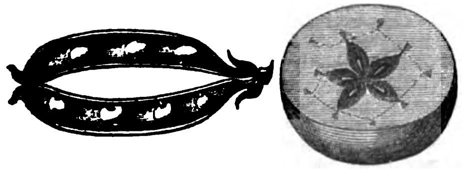
Pistil.—The pistil is the more or less filamentary body which in most plants rises from the centre of the flower terminating the axis of growth, and is surrounded by the stamens. The pistil represents the female part of fructification. Its parts are—1. The *ovary*, containing ovules or rudimentary seeds, and forming its more or less enlarged basal part; 2. The *style*, or filamentous part; and 3. The *stigma*, or enlarged club-shaped or cloven part forming the apex. The first and last of these are essential, and always present; but the intermediate one, the style, is sometimes not developed, as in the poppy, for example. The pistil consists organically of one or more carpels (folded leaves), which may either be syncarpous (united into one) or apocarpous (separate); in the latter case, we have two or more pistils in the flower.

Having thus briefly described the visible reproductive organs, let us now turn to their functional phenomena. When the flower expands, and its essential organs have arrived at maturity, the anther-valves open and emit the pollen-grains; some of these fall upon the stigma, or terminal point of the pistil, where a peculiar tissue, formed of papillary or hair-like cells, is ready to retain them. A curious phenomenon is now observed. The pollen-grain—a single free cell—develops one or more tubes from its surface, these being formed by its inner membrane, which thus grows through the outer one. These tubes are destined to reach the ovules at the base of the pistil, and thus to carry down from the pollen-grain the matter or influence necessary for fertilisation. The tube, accordingly, penetrates the soft tissue of the stigma, and passes down the centre of the pistil, where a loose conducting tissue is specially formed to facilitate its progress. In this way the pollen-tube often acquires

a length several thousand times greater than that of the pollen-cell whence it was produced, its nourishment being derived from the surrounding tissues which envelop it. Mohl regards the development of this filament or tube as indicating a new analogy between the pollen-grain and the spore of cryptogamic plants; for it is, in fact, a process of germination. The length of time required for the growth of the pollen-tube down to the ovule, is very various in different plants, and by no means depends upon the length of the style: thus in the night-flowering cactus, which has a style nine inches long, the pollen-tube reaches the ovules a few hours after the pollen has been applied to the stigma; while in the pine, where there is no proper style, a whole year elapses before the pollen-tubes reach their destination. The lower extremity of the pollen-tube ultimately comes into contact with the ovule, and enters the foramen or micropyle of the latter, so as to reach the embryo sac pre-existing there. According to some physiologists, the apex of the pollen-tube enters or introverts the embryo sac, and develops within itself the rudiment of the future embryo; others think that the tube merely comes into contact with the sac, in which a germinal vesicle has been previously formed ready for impregnation. It is not yet known whether the cavity of the pollen-tube and the embryo sac become actually continuous by absorption of their respective walls at the point of contact; and other questions are still the fertile subjects of learned discussion. However these details may be ultimately settled, it will suffice to state here, in general terms, that the result of the access of the pollen-tube to the ovule, is the production of an embryo in the latter, and that the ovule, with its contained embryo, ultimately ripens into a seed. Fertilisation with pollen is essential for the production of fertile seeds, although the ovule exists previous to the act. Fruits may, in some instances, swell and ripen without any process of fertilisation; but in that case, they will not contain fertile seeds capable of producing new plants.

It is not essential for success in this process that the pollen should fall immediately from the anthers upon the stigma, for we have several historical facts which indicate that pollen may retain its vitality unimpaired, in the manner of seeds. Thus, in the cultivation of the date-tree, it is necessary to bring the fruitful plants under the influence of the male flowers; but on one occasion, during a civil war in Persia, the male date-trees of a whole province were cut down by the invading troops, that the fructification of the fertile trees might be prevented, and the season's crop thus destroyed. But the inhabitants, apprehending such a result, had been careful previously to gather the pollen, which they preserved in closed vessels, and thus were enabled to impregnate their trees when the country was freed from the destroying enemy. The pollen-grains of the date and of the European palm (*Chamærops humilis*) are said to have retained vitality after the lapse of eighteen years.

Seed-vessels are various in form—as, for example, in the case of the pea (*a*), the vessel is a *legume*, or pod; in the apple (*b*), it is a *pome;* and in the filbert, a nut.



a. *b.*

All our esculent fruits are in reality so many vessels or receptacles for the seeds; and the various forms in which they appear are individually suitable to the purposes of their growth. As we have already indicated, the seed contains the *embryo*, or germ, of the future plant, which is generally surrounded by a nutritious substance termed the albumen, destined for the support of the young plant before its organs are sufficiently matured to allow of its supporting itself. This albumen varies very much in quantity, sometimes being much smaller than the embryo; while in other cases, as in the coco-nut, it weighs as many or more ounces than the embryo does grains. Its texture is variable. It is generally fleshy, as in the pea and bean; but sometimes it is farinaceous or floury, as in the wheat and in the marvel of Peru; at other times it is oily, as in linseed; horny, as in the coffee; or even stony, as in the palm-like plant whose seed forms the substance called vegetable ivory. If the embryo consists of one seed-lobe or cotyledon, as the wheat, it is said to be *monocotyledonous;* if of two, as in the beech and oak, *dicotyledonous*—and these terms are generally used respectively for endogenous and exogenous; while cryptogamous, or flowerless plants, from being propagated by spores instead of seeds, are said to be *acotyledonous*—that is, without any cotyledon whatever.

FRUCTIFICATION OF FLOWERLESS PLANTS.

As already stated, the lowest forms in which vegetables make their appearance are those of the *cryptogamous*, or flowerless orders—such as the ferns, lichens, mosses, sea-weeds, and fungi. In these, the mode of fructification is very remarkable, and quite different from that of flowering-plants. They have neither flowers nor seeds, but are propagated by minute unicellular bodies called *spores*.

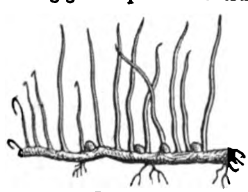
Ferns.—In the ferns (*Filices*), which are the largest and most highly organised of the flowerless orders, little brown spots, called *sori*, may be seen on the under sides of the leaves or fronds (see figs.). Each of these is

Ferns, shewing the Sori on the back of the Fronds.

composed of a number of minute membranous capsules (*thecæ*), which contain the reproductive spores, and which are often furnished with an elastic ring, for assisting in rupturing the spore-case, and thus facilitating the dispersion of the spores. These spores are not the result of a process of fecundation similar to what has been described in the case of flowering-plants; here the order of reproductive phenomena seems to be reversed. Impregnation takes place not upon the mature frond, but upon the infant fern, while as yet scarcely visible to the naked eye. The spores, when scattered over the soil, give rise to minute cellular expansions of tissue resembling liverworts, upon which male and female bodies, called respectively antheridia and archegonia, are produced. The former emit spermatozoids, which move about freely, by means of attached cilia. The archegonia have a central canal, leading down to a large globular cell. According to Count Suminski—to whom we are indebted for a knowledge of these remarkable phenomena—a spermatozoid enters the archegonial canal, reaches the globular cell, and its end is there developed into the embryo cell. This cell divides, and is soon developed into an embryo,

with a bud above and a radicle below; and then the circinate fronds shewing the genuine fern-structure arise. As an order, ferns are very widely distributed, generally consisting of a number of leaf-like members called *fronds*, which are the only visible portion of the plant. In some species, however, the stem rises above ground to the height of thirty or forty feet, forming the well-known *tree-ferns* of New Zealand and Tasmania.

Fern Allies.—In the horse-tails (*Equiseta*) of our marshes and ditches, the spores are placed on bracteated spikes, terminating the stems. Each spore is furnished with an elastic filament, which is at first coiled around it, but which, in its endeavour to uncoil, makes the spore jerk and leap as if alive. The horse-tails are herbaceous perennial plants, having hollow striated stems, these being either simple or branched. In point of size, they are now insignificant members of the vegetable kingdom; but geology has revealed the gigantic proportions they bore in ages long past, when, instead of slender stems of a foot or two high, they reared their gigantic pillar-like trunks to a height of twenty or thirty feet. The spores of the pillworts (*Marsileaceæ*) are enclosed in little ball-like receptacles at the bases of the leaves (see fig.); the club-mosses (*Lycopodiaceæ*) have little cone-like spikes at the tips of their branches, among the scales of which lurk small spores, while large ones occupy the axils of the leaves lower down.



Pillwort.

In the true mosses (*Musci*), the spores are enclosed in urn-shaped capsules, which stand out from the leaves on slender hair-like stalks. In the liverworts and lichens there is a somewhat similar provision; and in the algæ (sea-weeds), the spores are often enclosed in the substance of the plant.

The *fungi*, or mushroom tribe, are extremely diversified in their size, shape, colour, and consistence. They are entirely composed of cellular tissue. The common field-mushroom is one of the best known, and may be cited as typical of the family; but the mould on cheese, stale bread, the mildew on vines, the rust on corn, and many other minute and yet unobserved appearances of a similar nature, are all fungi. Their organs of reproduction consist of spores variously arranged in different tribes, presenting resemblances in some to the lichens, and in others to algæ; but the whole subject of reproduction in fungi requires further investigation, although valuable contributions to our knowledge have recently been made.

There is still much to learn respecting the cryptogamic orders, which yearly receive increasing accessions of students, for it is in these plants that the whole vital phenomena of vegetation can best be studied. 'We are entirely ignorant,' says Professor Lindley, 'of the manner in which the stems of those that are arborescent are developed, and of the course taken by their ascending and descending sap—if indeed in them there really exist currents similar to those of flowering-plants; which may be doubted. We know not in what way the fertilising principle is communicated to the sporules or reproductive grains; the use of the different kinds of reproductive matter found in most tribes is entirely concealed from us. It is even suspected that some of the simplest forms—of algæ and fungi, at least—are the creatures of spontaneous growth: and, in fine, we seem to have discovered little that is positive about the vital functions of those plants, except that they are reproduced by their sporules, which differ from seeds, in germinating from any part of their surface, instead of from two invariable points.'

General Economy of Flowerless Plants.—Insignificant and lowly as the cryptogamia may appear to the eye of the common observer, they are nevertheless important auxiliaries in the operations of nature. It is true that man and his works may suffer from their ravages, that mildew, rust in corn, and other microscopic forms of vegetation, by their rapid increase and destructive effects on the substances from which they spring, may cause incalculable damage; but this very scourge provides an incentive to intelligent prevention and care, while in creation there are no more useful scavengers of decaying matter than the fungi. In a dry season, for example, and on a favourable soil, rust rarely makes its appearance: certain conditions are necessary for its development; and it is to obviating these that the farmer must look for exemption from this destructive malady in his crops. It is said that it arises in many cases from the over-manuring of fields; the grain is overloaded with nourishment, and the dormant fungi, brought into a condition of development, speedily shew their destructive properties. The tendency to rust may be neutralised by steeping the seeds before sowing in a corrosive solution, or strong brine; but the same end may be better secured by not over-manuring, or by a free use of saline manures. Again, most of the fungi existing only by the absorption of fetid exhalations, and rapidly depriving them of their insalubrious properties, execute duties analogous to those of certain tribes of insects—maggot-flies, for instance—and in this respect have been appropriately associated with these animals as the 'scavengers of nature.'

It will now be understood that mould is a fungus, produced by a previous deposit of germs in the tissue or on the surface of the object on which it grows. The proximate cause of its development is generally damp, and without this condition, the embryo remains in a dormant state. Still it may be asked, how cheese happens to have green mould at its very centre?—the reply is, that the germs floating in the atmosphere had various opportunities of finding admission into this article of diet. They may have been deposited on the grass of a field; the grass was eaten by the cow, and the germs were so lodged in the milk; or, what is more probable, the germs fell upon the curd, and there lay concealed till a certain dampness in the cheese brought their vegetative powers into operation. It is well known that the exposure of curd for a day to the atmosphere will have the effect of producing cheese liable to mould. A fully more surprising instance of fungus vegetation in a secluded situation, is that which occurs in the fermenting of yeast and other substances. Fermentation is, in one respect, a chemical process, forming a first step towards dissolution; but the action is also vegetative. The whole mass of matter gradually assumes the condition of active vegetative growth. The fungus germs which had been incorporated in the material begin to live and expand, each being a plant which grows and gives rise to new plants of the same species, until the entire fermenting principle is exhausted.

One great object which nature has in view by the germination and dispersion of the algæ, mosses, and lichens, is clearly that of preparing the way for a higher order of vegetation. It cannot possibly escape our observation that the tendency to vegetate is a power restless and perpetual. We hew a stone from the quarry, and place it in a damp situation, on the ground or in a wall, and shortly a green hue begins to creep over it. This is the commencement of a vegetable growth, produced by germs floated in the atmosphere; and being attached at random to the stone, have been brought to life through the agency of the moisture. Other stones equally exposed, but in dry situations, have also received a clothing of these germs, but circumstances not being suitable, they have not been developed: give the moisture, and they will immediately appear. We hew another stone from the quarry, and build it into the

pier of a bridge, just within the surface of the water: shortly, a kind of green alga will appear; but the wet being in greater abundance, and more continuous, the growth will become more luxuriant than that of the terrestrial wall. Instead of the simple green coating, we have the addition of long filaments resembling hairs (*Conferva*), which float and accommodate themselves to the water around.

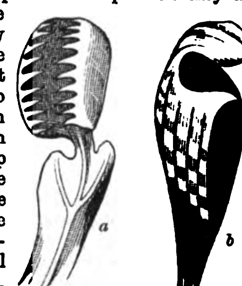
The inquiry may perhaps here be made—supposing that nature designs this species of growth to be a forerunner of a higher order of vegetation, how is that result to be brought about? To answer this, we must take an expansive view of the subject, and not confine ourselves merely to one department of science. Nature is incessantly working out vast ends by humble and scarcely recognisable means. It seems to be a principle that nothing shall remain stationary or unchanged. The whole surface of our planet is every instant altering in its features: mountains are being washed down into the plains, rocks are mouldering into soil, the sea is filling up at one place and encroaching on the land at another, and water-courses are constantly shifting their outlines. The duty of filling up seas, ponds, lakes, and rivers, is consigned to diverse means within the animal and vegetable economy; and one of these is the growth of algæ and other aquatic plants. Take a pond of water, and shut off its means of supply from rivulets and springs, and then observe what an effort nature will make to fill it up. The sides and bottom become speedily covered with a luxuriant crop of confervæ; other plants, which grow only in water, begin to make their appearance, their seeds being wafted thither by winds; at length the superficial matting of herbage is able to support the weight of birds; there is alternate vegetation and decay; finally, the pond is filled up, and a forest of the highest order of trees may in time cover the site of the original humble confervæ. What, indeed, are the extensive peat-mosses but lakes and pools choked with vegetable matter, which remains in a half-reduced condition. Thus we see that the green alga which grows upon stones in the water, humble and apparently insignificant as it is, performs a distinct part in creation necessary to work out the important designs of Providence.

SPECIAL PHENOMENA OF VEGETATION.

In addition to the ordinary functions of the organs, which are common to all plants, there are certain anomalous phenomena which cannot be reduced to regular laws, and which merit notice in this place; the most remarkable of these are the occasional *irritability* and *movements* of plants.

Irritability.—The irritability of animals depends entirely on their nervous system; but as plants have no nervous system, their irritability is more difficult to be accounted for. Dr Darwin indeed asserts that plants are only an inferior kind of animal, and that they, or at least some of them, have a brain and a stomach, and are endowed with the lower senses. According to this fanciful doctrine, the medulla, or pith, was made the seat of sensation, and was considered analogous to the spinal marrow of animals. The doctor, however, had no followers, as his hypothesis presented too many difficulties to be even partially believed. The principal phenomena of vegetable irritability may be divided into three kinds—namely, those caused by atmospheric influence, those depending upon the touch of other bodies, and those which appear to be perfectly spontaneous. Atmospheric influence occasions the closing of the leaves over the extreme point of the young shoot at night, as may be observed in the chickweed and several other common plants. The folding of some flowers in the absence of the sun, and the opening of others as soon as that luminary has withdrawn its beams, are ascribable to a similar cause. The pimpernel closes its flowers on the approach of rain. Most blossoms expand during sunshine; but the evening primrose, on the contrary, will not open its large yellow flowers till the sun has sunk below the horizon; and the night-flowering cereus only expands its magnificent blossoms about midnight. Some flowers are so regular in their hours of opening and shutting, that Linnæus formed what he called *Flora's Time-piece*, in which each hour was represented by the flower which opened or closed at that particular time. Solar light is the principal agent in producing these phenomena; but in some cases flowers have been known to open by artificial light. Decandolle found blossoms expand beneath a lamp nearly as well as beneath the sun itself; and the crocus and gentian, which close at night, have been known to expand as wide as possible when gently exposed to the light and heat of a fire. One of the most remarkable circumstances respecting the effect of atmospheric influences is, that the same causes do not affect all plants, and yet no peculiarity of construction has been discovered in those that are so affected to distinguish them from those that are not.

The irritability produced by external touch is a familiar but little understood phenomenon. The movements of the sensitive plant are well known; and it is also known that if the ripe seed-vessels of the noli-me-tangere be touched in the slightest manner, they will open with elasticity, and scatter their contents. In the same manner the fruit of the squirting cucumber throws out its seeds, and the moist pulp in which they are contained, with great violence, and to a considerable distance. The stamens of the barberry, when touched with a pin, spring forward towards the stigma, after which they return to their original position; while the column of the stylidium, which includes the style and stamens, and which generally hangs on one side, when touched, springs with a jerk to the other side of the flower. The most remarkable instance of irritability by contact is that exhibited by Venus's fly-trap (*Dionæa muscipula*), a native of North America. Its flowers have nothing remarkable about them, except that their petals roll up when they are about to decay; but the leaves are very curiously constructed. They have broad leaf-like petioles, at whose extremity are two rounded fleshy lobes, which form the real leaf, and which are armed with strong sharp spines, three on the blade of each lobe, and a fringe of longer spines round the margin (*a*). When an insect touches the central spines, the leaf collapses, and the poor insect is caught; being either impaled by the central spines, or entrapped by the others. The leaf then remains closed, the fringe of long spines being firmly interlaced and locked together till the body of the insect has decayed. Sarracenia, or side-saddle flower, the leaves of which have a pitcher-shaped petiole (*b*), also forms a trap for flies and other insects, but it does not display irritable phenomena.



a, Leaf of Venus's Fly-trap.
b, Leaf of Sarracenia.

The *spontaneous movements* of plants are equally difficult to be accounted for with those occasioned by atmospheric phenomena or by external touch. It is true that the leaves elongate, the flowers expand, the anthers burst, and the seed-vessels open spontaneously; but these are movements caused by the progressive development of the plant, and subjected to regular laws. The spontaneous movements to which reference is now made are quite different—as, for example, those of the leaves of *Hedysarum gyrans*. This plant has compound leaves, the terminal leaflet of which displays a slight

oscillatory motion; but the side-leaflets have such eccentric movements, as to render it difficult, if not impossible to explain them, and which might appear, indeed, to a fanciful mind as though the whole plant were actuated by a feeling of caprice. Generally, all the leaflets twist and whirl themselves about in an extraordinary manner, though the air of the house in which they grow is perfectly still; but frequently the leaflets on only one side will be affected, and sometimes only a single leaflet will move, or all will become motionless together; and when this is the case, it is quite in vain to attempt to set them again in motion by touching them; though sometimes in a moment, as if from the pure love of mischief, after the touching has ceased, the leaflets will begin to move again as rapidly as before. In like manner, the side-leaflets frequently continue their eccentric movements all night, while the terminal leaflet remains quietly folded up, and apparently fast asleep. Cold stops the motion of the leaves, which begins again so soon as the heat of the stove in which the plant grows is renewed.

Plants may be deprived of their irritability by keeping them without water, when they become flaccid; or by watering them with a poisonous liquid; in which case they lose not only their irritability, but their lives. Life, indeed, appears to be intimately connected with irritability, which exists only in plants in a vigorous and healthy condition. The functions of vitality and irritability may be merely suspended without destroying life, by administering to them the same substances which produce stupor in animals.

Colour.—The colours of plants present many points of interest for the consideration of the student, and are connected with many important phenomena in vegetation. It is to colour, perhaps, more than to form, that vegetation, as a whole, often owes its importance in the landscape. The gay colours of plants usually reside in the corolla, the leaves being usually some shade of green; but in the case of sea-weeds and other cryptogams, the whole plant is often of a bright red, or green, or olive, according to the species, a character which has afforded the basis of the classification of sea-weeds now in use. In flowering-plants, colour is usually of much less importance, and so variable as to give no aid in classification.

The green colour of leaves, and the gay colour of flowers, depend upon different kinds of colouring-matter contained in the cells of the plant, for the cell-walls are without colour themselves. In the green parts of plants, this colouring-matter is in the form of microscopically minute green granules of chlorophyll, which are only produced under the action of light; hence plants grown in the dark are etiolated. The changes which it undergoes, according to its state of oxidation, explain the tints which green leaves acquire in autumn. According to Schleiden, the yellow leaves of autumn contain proportionately more wax than the green leaves of summer, and the yellow rind of ripe fruits more than the green rind of unripe fruits.

The colours of parts not green are due to a different kind of colouring-matter, termed chromule, whose chemical relations to chlorophyll have not been fully investigated. Chromule is usually diffused throughout the sap of the cells; as in the flower of the tulip, for example, a strip of the epidermal tissue of which will shew well, under a common compound microscope, the beautiful arrangement of cells of different colours, so as to give the general effect seen in this gaudily painted flower. In some cases, however, chromule is found in the form of distinct granules. In the intensely blue part of the flower of Strelitzia Reginæ, these are spherical, while in the deep orange parts they consist of slender crescentically twisted filaments floating in coloured cell-sap. Although light is essential to the development of the green colour of leaves, its immediate action is not always required for the development of the chromule of flowers—a fact quite in accordance with the practice of florists, who keep their favourite dahlia and pansy blooms covered up in their later stages. In accordance with this, also, is the fact that flowers grown in the shade are seldom different in colour from those fully exposed to the air and light. The petals of the common buttercup and the lesser celandine are of as brilliant a yellow in town-gardens enveloped in the smoke of London as on any country hill; and roses always maintain their brilliant tints, even when the bushes on which they are produced are evidently dying for want of a clear atmosphere. Flowers may be made to change their colours by the influence of the soil in a most remarkable manner. The petals of the common hydrangea, which are naturally pink, are said to be made blue by planting the shrub in soil impregnated with iron or providing it with charcoal. The change produced in tulips, carnations, heart-eases, &c., is still more extraordinary. The flower of a seedling tulip is generally uniform; and after remaining of this colour two or three seasons, it will suddenly *break*, as the florists term it, into the most brilliant and varied tints of rose, white, yellow, brown, or purple, without leaving any trace of the original colour. To produce this change, florists try a variety of means, all of which have relation to the soil; for example, they sometimes keep their tulips in poor soil, and then suddenly transplant them into one exceedingly rich; or they reverse the process: at other times they change them suddenly from a sandy to a clayey soil. Even the chlorophyll of plants is often developed under circumstances where the influence of light is very slight, and would appear to depend in some measure upon other agents: it is well known that ferns and mosses have been found green in mines where they have grown in almost total darkness; and green and red sea-weeds of the most brilliant tints grow at great depths in the ocean, where the light, being weakened by passing through such an immense body of water, can have but little colouring effect.

Although it has been stated by Ruskin that 'the natural colour of objects never follows form, but is arranged on a different system,' the recent investigations of Professor Dickie on the relations between colour and form in plants seem to indicate a different result. He finds—1. That in polypetalous and gamopetalous flowers, of regular form—such as the primrose, gentian, and pimpernel—the distribution of colour is uniform on the different petals, whether free or in cohesion, whatever be the number of colours present; 2. That flowers whose form is irregular—as, for example, papilionaceous flowers, where certain petals are larger than the others—present an equally irregular distribution of colour, whether one or more colours be present; 3. That different forms of corolla, in the same head of flowers, often present differences of colour; but all of the same form agree also in colour.

The colouring-matter extracted from vegetables is of great economical value, being extensively used in the art of dyeing. Some of these dyes resemble the natural colour of the parts from which they are derived, such as saffron, which is the yellow stigma of a species of crocus; but others, as woad and indigo, are totally dissimilar, being blue or black, when the native vegetable texture is green.

Fragrance.—The cause of fragrance in flowers has never yet been fully explained. We know that all organised bodies consist partly of volatile matters, and thus we can readily account for the odours given out by decaying animal and vegetable substances, as they evidently proceed from the volatile parts being liberated by decomposition. The fragrance of flowers, however, escapes while the plants are in a living state, and that most abundantly when they are in vigorous and healthy condition. Besides the flowers, other parts of living plants frequently exhale fragrant odours—such as the leaves of the myrtle and geranium, and the wood and bark of pines. All these odours proceed from oily or

resinous matters contained in the receptacles of secretion; but the laws which regulate their liberation, and define their physiological uses, are as yet imperfectly known. Some botanists consider them to be part of the excrementitious matter which is thrown off by plants when it is no longer necessary to their growth. It is well known that plants are most fragrant in damp weather. The petals of roses and other flowers retain their fragrance when dried. The fragrance in leaves, bark, and wood, in many cases serves to preserve them from the attacks of insects; as we find that the smell of the red and Bermuda cedars, of which pencils are made, and of camphor—also a vegetable product—are sufficient to keep the moth and some moulds from attacking substances with which they are in contact. The odours of plants are of three kinds: permanent, fugitive, and intermittent. Permanent odours are those given out slowly by the plant, not only whilst it is living, but also after the fragrant part has been separated from the living plant. Of this kind are the odours of fragrant wood, of the dried petals of roses, and some other flowers. Intermittent odours are the most difficult to be accounted for by the vegetable physiologist. It is well known that the night-smelling stock, and several other plants, which are entirely devoid of scent during the day, are delightfully fragrant during the night. One of the orchideous plants produces its powerful aromatic scent only when exposed to the direct rays of the sun; and the flower of the night-blowing cereus is said to be fragrant only at intervals of about half-an-hour during the time of its expansion, preserving the same kind of intermittence even when separated from the stem.

Tastes.—The tastes produced by vegetable substances are generally recognised as sweet, acid, bitter, astringent, austere, or acrid. The juice of the sugar-cane, for example, is sweet; that of an unripe apple, acid; the aloe, bitter; the leaf of the bramble, astringent; and the cranberry, austere. It has been already stated that the ascending sap is at first insipid, and that it gradually acquires the peculiar taste of the plant; but it is only in the descending juice that the taste-yielding principle is fully developed. Why the taste of one vegetable should differ from that of another grown in the same soil, the physiologist is unable to determine; he as yet only understands a few of the causes by which tastes may be modified or destroyed. The principal influences which modify the tastes of plants are atmospheric and solar; light, exposure, and warmth being those under which taste, as well as all other qualities of vegetables, are most fully developed. Every one is acquainted with the blanching effects of *earthing*, as exhibited in celery or in the shoots of the common rhubarb. The fruits grown in our own island during a wet and sunless season, are insipid compared with what they are in a dry and bright summer; and the general vegetation of the arctic and temperate regions is less powerful in kind than that of the tropics. As a general law, it may be stated that the drier and warmer the situation, the more exposed to light, and the slower the growth of any vegetable, the more intense is its peculiar flavour.

Luminosity, Heat, Electricity.—The luminosity of plants—that is, the evolution of light either from living or dead vegetable structure—is a rare and curious phenomenon. Flowers of an orange colour, as the marigold and nasturtium, have been occasionally observed to present a luminous appearance on still warm evenings; this light being either in the form of slight electric-like sparks, or steadier, like the phosphorescence of the glow-worm. Certain fungi, which grow in warm and moist situations, produce a similar phosphorescence; and decaying vegetables, like dead animal matter, have been observed to emit the same kind of luminosity. This phenomenon seems connected with the absorption of oxygen; and the parts emitting it are said to be most luminous when immersed in pure oxygen, and cease to emit it when excluded from that element.

The evolution of heat by living plants is a more common phenomenon. We are aware that warm-blooded animals have the power of keeping up a certain temperature within them, which varies at certain stages of their growth, and perhaps periodically. This result is obtained by respiration—the oxygen of the atmosphere uniting with the carbon of their blood, and producing a kind of combustion. A similar, though less understood phenomenon, seems to take place in the respiration of plants. In germination, heat is sensibly evolved; a piece of ice placed on a growing leaf-bud will dissolve, when it would remain unchanged in the open air; and experiment has proved that the surface of plants is three or four degrees higher than the surrounding medium. Again, the internal temperature of a large trunk is always higher than the surrounding atmosphere, and though young shoots are sometimes frozen through, the general structure both of the wood and bark is such as to conduct heat so slowly, that the internal warmth is seldom reduced beyond what seems necessary to the maintenance of vitality. Generally speaking, it may be asserted that plants possess an internal vital temperature, and that in the so-called process of respiration—the giving off of carbonic acid or oxygen, as the case may be—a certain degree of heat is evolved; but precise experimental results are wanting. During the flowering of certain plants, such as species of Arum and the Victoria Regia, a sensible amount of heat is evolved, raising the temperature inside the flower higher than that of the surrounding atmosphere.

The connection of electricity with vegetable growth has recently excited the attention of physiologists; but little positive information has yet been ascertained. It has been long known that growth takes place with great rapidity during thundery weather; but this may result from the nitrogenised products of the showers which then fall, as well as from the effects of electricity. The progressive states of vegetable growth are the result of chemical changes; and as these changes are more or less accompanied by electricity, it is supposed that plants evolve electricity as well as heat. The general electric state of plants is said to be *negative;* and some have attempted to connect the luxuriant vegetation of the tropics with the thunder-storms of these regions, on the supposition that when the atmosphere is *positively* electrified, the two opposite states will give rise to such commotions. Of late years, attempts have been made to apply the principle to agriculture; conducting-wires have been laid around experimental plots, but with such varied, and even contradictory results, as to preclude anything like a determinate conclusion.

SECRETIONS AND EXCRETIONS OF PLANTS.

Substances of varied properties are secreted by plants, and otherwise formed in their tissues according to their respective natures, and their healthy or diseased condition at the time of secretion. Some of these substances are produced by the ascending sap; but the greater number are deposited by the elaborated or proper juice, and consequently are seldom secreted during spring or early summer. The intensity of those derived from the latter source depends in a great measure upon the influence of solar light; hence they are much stronger, and more abundantly produced, in tropical than in temperate climates. From the manner in which many of these are deposited or ejected, they appear to be of no utility in the vegetable economy. Some of them may be regarded as *excretions* as well as *secretions;* but whether they are to be considered as essential components of the sap, or evacuations necessary to the healthy condition of the organs, has not yet been determined. Being exceedingly varied in their properties, they are of great utility to man as articles of food, medicine, ornament, and luxury.

The economical applications of vegetable secretions and excretions are so numerous, that it would be impossible, in our limited space, to enter upon anything like details. It is even difficult to attempt any classification of them; for, though differing in their properties and external appearance, many of them are identical in chemical composition, and, subjected to peculiar treatment, readily pass into new and singular combinations. Some, for instance, are saccharine, as the juice of the sugar-cane. Many are oleaginous, balsamic, or resinous; some are narcotic, aromatic, or mucilaginous; while others are astringent, purgative, or poisonous. For examples of these divisions, the reader has only to recall to mind such substances as palm and olive oil, myrrh, resin, opium, camphor, gum-arabic, tannin, gamboge, prussic acid, aloes, colocynth, and a thousand others of everyday familiarity.

Besides the proper excretions and secretions, there are several adventitious substances found in plants, which are not the products of vital organisation. Lime, for instance, is found in the ashes of many plants in union with acids; sometimes it is excreted in the form of a thin crust on their leaves, and in other cases in peculiar cells. Silica also occurs in considerable quantities, especially in the stems of reeds and grasses; it forms the glossy pellicle of the cane, and is sometimes found in the joints of the bamboo, where it is deposited in a soft pasty mass, called *tabasheer*, which ultimately hardens into pure semi-transparent silica. Besides these earths, there are various metallic oxides and salts, and the well-known alkalies—potash and soda. The physiological uses of such products are but imperfectly known. Many of them—such as starch, gum, sugar, and the fixed oils—directly administer to the support of the young plant and to the formation of new tissues. Others, again—such as silica and metallic oxides—give hardness and stability to the stems and branches; some give elasticity and pliancy to the young shoots, thereby preventing them from being broken by winds; and several—as tannin, for example—seem to administer to the durability of the woody fibre by their properties of resisting putrefaction.

METAMORPHOSES OF PLANTS.

The metamorphoses of plants, in the general sense of the term, form one of the most interesting sections of Vegetable Physiology. Technically, it is termed *Morphology*—that is, a consideration of the changes and transformations which various parts of plants undergo, either from natural or artificial causes. We know, for instance, that many plants are made to change their appearance and qualities by cultivation; that by grafting, hybridising, and other means, the gardener can change the size, colour, and qualities of his fruits and flowers: and that analogous changes take place in a state of nature—such as the conversion of petals into leaves, and leaves and branches into thorns and spines. It is also well known that flowers become double by changing their stamens into petals; and it is from a knowledge of such facts that botanists have asserted that all the parts of the flower and fruit, as well as the appendages of the stem or ascending axis, are modifications of a single typical organ, and may be considered *as leaves adapted to special purposes*. This doctrine, at first broached by Linnæus, and subsequently expounded by the German poet Goethe, is now very generally adopted.

The law which it seeks to establish may be stated to be this: that all the appendages of a plant have a common origin with the leaf, and may therefore successively assume the form and appearance of that primary organ. The branches of the stem take their origin from leaf-buds, and are clothed with branches and leaves by the same process as in the main stem. Towards the point of fructification, the leaves assume the form of bracts; these, again, are succeeded by the leaf-like sepals of the calyx; and next by the petals of the corolla. Within the petals are the stamens—which sometimes assume a leafy form—next the pistil, and ultimately the seed-vessels. Even the seeds are but leaves in another form. Thus, the growth and reproduction of plants may be regarded as a circle of leaf-like changes, the leaf, or some modification of it, being in all cases the organ which administers to the functions of vitality. We need scarcely enumerate instances of these conversions, for every one who has intelligently observed the common garden-plants around him, must have sometimes felt the difficulty of distinguishing between calyx and corolla—must have seen stamens assume the aspect of petals, and not unfrequently the whole floral organs appear green and leafy. And just as there is an indubitable passage from leaves to every other organ, so may any one organ be found to revert to the primary form of the leaf. One of the most striking examples to which attention can be drawn is that of the cherry. To say that the fleshy fruit of the cherry, with its central stone, is merely a modified leaf, may seem paradoxical; but such is the fact, as any one may demonstrate by examining the blossom of the double-flowered cherry, so common in shrubberies: in this variety, the stamens are changed into petals, and the ovary into a green leaf!

By cultivation and other artificial treatment, certain peculiarities assume in some plants a wonderful degree of permanency, and may be transmitted to successive races; though, generally speaking, if the artificial stimulus be not kept up, plants will return to their normal or natural condition. There are no such roots or tubers in nature as our cultivated beet, carrot, and parsnip; no leaf-buds like the thick succulent *hearting* of the cabbage; no flowers like our double roses, carnations, and ranunculuses; and no fruits like our delicious pears and apples.

The *hybridism* of plants is closely allied to the subject of morphology, and is, in fact, a process of transformation of an artificial character. As among animals two distinct species of the same genus will produce an intermediate offspring—such as the *mule*, which is the offspring of the horse and ass—so among vegetables, two species belonging to the same genus can be made to produce a *hybrid;* that is, a new plant possessed of characters intermediate between its parents. This power of hybridising is more prevalent among vegetables than animals; for the different species of *many* genera of plants are capable of producing this effect, if the pollen of one species be put upon the stigma of another. And this crossing may even be applied to separate genera. Hybrids have not the power of perpetuating their kind like naturally distinct species; for, though occasionally fertile in the second and third generations, they have never been known to continue so permanently. But though incapable of propagating beyond a limited period, the pollen of the parent species may be made to fertilise them, or their pollen to fertilise the parent; but in either case the new offspring gradually merges into the original species. Thus nature has wisely set a limit to the intermingling of species, by which they are preserved from ultimately running into confusion and disorder.

In an economical point of view, hybridism is of great value to man. By a knowledge of its principles, he has been enabled to modify the characters of natural species, so as to adapt them to his special purposes; and thus have arisen most of those beautiful varieties of what are termed florists' flowers, which now adorn the flower-garden. So also by crossing varieties of the same species, our grains, fruits, and kitchen vegetables have been brought to a high state of perfection. The size of one species has been assiduously amalgamated with the durability of another; the beauty of a third with the flavour or odour of a fourth; and so on with other qualities. The principles of hybridism will yet be more extensively applied; and it is not too much to expect that the perfection of our field and forest produce will yet rival that of our orchards and gardens.

SYSTEMATIC BOTANY.

BOTANY is the science whose purpose it is to investigate the Vegetable Kingdom. *Vegetable Physiology*—treated in the preceding sheet—is that department of the subject which explains the organisation and vital functions of plants; *Systematic Botany*, that which recognises their arrangement into groups, according to their form and structure. The former relates to functions which are common to all vegetables; the latter takes notice only of such peculiarities as serve to distinguish one species from another, or one family from another family. The vegetable kingdom is supposed to contain upwards of 100,000 species; and therefore, without some system of arrangement into smaller groups and orders, it would be difficult to acquire a knowledge of the special characteristics of plants, or to convey that knowledge to others by any process of description. It is the aim of Systematic Botany to obviate this difficulty, by classifying plants according to certain types and resemblances which are common to a number of species; thus making one description equally applicable to a class as to a species.

The advantages of classification in lessening the labour of memory and description, become strikingly apparent when we reflect on the difficulty which would exist were each plant to be known by an entirely distinct name. For example, there are many species of roses, all of which are known by the generic term *Rosa*, each having a second or specific name to designate it separately, as *R. centifolia*, *R. damascena*, &c. Now, if a botanist hear of a plant called *Rosa*, though its specific name be quite new to him, he has instantly a general idea of what sort of plant it is, from his previous knowledge of the common characteristics which belong to the genus *Rosa*. The principle of classification is to assemble those plants which bear most resemblance to each other; and this has been done in different ways by different botanists; each method being called the *system* of the individual who devised it—as Tournefort's system, Linnæus's system, Jussieu's system. Of the several systems which have been suggested, only two are in use at the present time—namely, that of Linnæus, the great Swedish naturalist (1707–1778); and the Natural System, in its numerous modifications, that of Jussieu, an eminent French botanist, who, during the long period between 1789 and 1836, was closely engaged in improving the nomenclature and arrangement of the vegetable kingdom, having afforded the basis of those mostly in use.

The system of Linnæus is founded on the *sexes* in plants—the number, situation, proportion, and connection of stamens and pistils, which are regarded as respectively the male and female organs, being chosen to supply characters for the classes and orders. This system appears at first sight extremely simple, as it depends entirely on the counting of so many visible parts; but it is very uncertain, as the number of stamens often differ, from accidental circumstances, in plants of the same genus; and it tells nothing of the plant but its class and order, which lead only to the discovery of its technical name, as plants of the most opposite qualities frequently agree in the number and disposal of their sexual organs. This mode of classification is known among botanists as the Sexual System, or the *Artificial System*, because it is founded on mere artificial enumeration, on a single series of characters, and not upon natural qualities or resemblances of the plants so arranged. That of Jussieu, on the contrary, is founded on the natural affinities of vegetables; and the botanist who is acquainted with its principles can at first sight assign any plant to its proper class and order, as there is always a general resemblance among the plants belonging to the same natural order. Again, knowing the order, which is usually typified by some common plant, he can predict as to its properties—a species of information which the artificial system does not attempt to convey. Jussieu's method has been greatly improved since the time it was suggested, particularly by the late Professor De Candolle of Geneva; and it is his modification of the original plan, with further improvements, which constitutes the most generally adopted *Natural System* of the present day.

According to both systems, plants are divided into classes, orders, genera, species, and varieties. A *class* consists of plants resembling each other in some grand leading feature, and as strongly differing from another class as mammalia do from birds, for example. Thus, flowering-plants with one cotyledon, whose trunks increase in thickness from within—as the palm—form a distinct class; while flowering-plants with two cotyledons, and whose trunks increase by external layers, constitute another class. An *order* consists of plants still more closely allied, so that many orders may be found in the same class. Thus, as ruminant or cud-chewing animals form an order of mammalia, so do the leguminous or pod-bearing plants constitute an order of dicotyledonous vegetation. A *genus* consists of plants so very closely allied, that they may be compared to members of the same family. The pea, for example, constitutes a genus of leguminous plants, just as sheep form a family of the ruminants. A *species* may be compared to one of the members which compose the family; thus the garden-pea and sea-pea are different species of the same genus. A *variety* is merely a departure from the common appearance of the species in trivial characters, or differences which arise from climate, situation, greater or less humidity of soil, and other accidental causes. The boundaries between species and varieties are often very vague, Mr Babington and other botanists regarding those plants as species which others consider mere varieties; but much doubt might be removed by attending to the fact, that a species reproduces itself from seed, and is always persistent under the same circumstances, whereas a variety has often a tendency to revert to its parent species, unless propagated by cuttings, and fostered by artificial means. A *hybrid* is a plant raised by fecundating the stigma of one species with the pollen of another—a process which occasionally occurs among plants in a wild state, but is more common in cultivation. Unless perpetuated by artificial processes, they soon die out, or revert to their original stock.

In botanical nomenclature, the name of every plant consists of two words; the first is the name of the genus, and the second that of the species—as, for example, *Quercus alba*, the white oak. When three names are given, the third signifies that the plant is a variety; and this is sometimes more strongly marked by using the contraction *var.* before the third name—as, *Quercus Ilex* var. *crispa*, the curled-leaved variety of that tree. The third name is for the most part omitted in botanical catalogues, and the varieties indicated by letters of the Greek alphabet—observing that the varieties begin with the letter β—as, *Quercus Ilex β. crispa*.

The primary arrangement of plants, according both to the artificial and natural system, is into those with flowers and those without flowers. The first division, or that which includes the flowering-plants, is distinguished

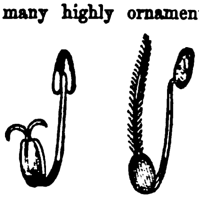
by the name PHANEROGAMIA, and in them the organs of reproduction are apparent. It comprehends all the trees and shrubs used in the economical arts, as well as the common ornamental plants of our gardens, and, in short, all those that have distinct organs—as leaves, branches, flowers, and proper seeds. The second division, known by the term CRYPTOGAMIA, embraces, as the name implies, those plants in which the organs of reproduction are not apparent—as the ferns, lichens, mosses, and sea-weeds. They have no flowers nor seeds, in the common acceptation of these words, and their *fronds* or leaves are very different from those of flowering-plants; instead of flowers, fruit, and seed, they are furnished with little cases or *thecæ*, and in these are lodged the reproductive spores, minute as the particles of the finest dust. Here the resemblance between the two systems ceases—their classes and orders being arranged on totally different principles. We shall present, in the first place, an outline of the Linnæan system, both on account of its priority and simplicity, and as an initiatory step to gaining a knowledge of the different forms of flowers. It is true that it is now disused by most men of science; but for the reasons already stated, as well as from the fact that many excellent works have been arranged on its plan, it is necessary that the general reader, as well as the botanist, should have an acquaintance with its leading features.

THE LINNÆAN SYSTEM.

The sexuality of plants had been discovered before the time of Linnæus; but as far as is now known, he was the first who suggested the adoption of this characteristic as a basis of classification. According to his system, the vegetable kingdom is divided into twenty-four *Classes*, founded upon the number, the proportionate lengths, the connection, or the situation of the stamens. These classes are again subdivided each into one or more *Orders*, depending upon the number of the pistils, the presence or apparent absence of a seed-vessel, its shape, or the number and connection of the stamens, or on the arrangement of the florets. Terms compounded of the Greek numerals and the word *andria*, or male, are for the most part used to designate the classes; and similar compounds of these numerals, and the word *gynia*, or female, are employed to designate most of the orders. The following synopsis presents at one view an outline of the system:—

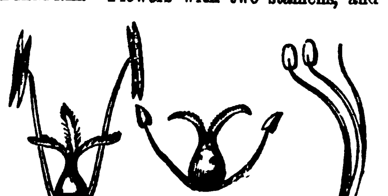
CLASSES.		ORDERS.
1. Monandria, . . .	1 stamen, ...	has 2—Monogynia and Digynia, or 1 and 2 pistils.
2. Diandria, ...	2 stamens, ...	″ 3—Monogynia, Digynia, and Trigynia.
3. Triandria, ...	3 ″ , ...	″ 3—Monogynia, Digynia, and Trigynia.
4. Tetrandria, . . .	4 ″ , ...	″ 3—Monogynia, Digynia, and Tetragynia.
5. Pentandria, ...	5 ″ , ...	″ 6—Mono., Di., Tri., Tetra., Pentagynia, and Polygynia.
6. Hexandria, . . .	6 ″ , ...	″ 4—Monogynia, Digynia, Trigynia, and Polygynia.
7. Heptandria, ...	7 ″ , ...	″ 4—Monogynia, Digynia, Tetragynia, and Heptagynia.
8. Octandria, . . .	8 ″ , ...	″ 4—Monogynia, Digynia, Trigynia, and Tetragynia.
9. Enneandria, ...	9 ″ , ...	″ 3—Monogynia, Trigynia, and Hexagynia.
10. Decandria, ...	10 ″ , ...	″ 5—Monogynia, Digynia. Trigynia, Pentag., and Decagynia.
11. Dodecandria, from 12 to 19	″ , ...	″ 7—Mono., Di., Tri., Tetra., Penta., Hexa., and Dodecagynia.
12. Icosandria, ″ 20 or more	″ , on the corolla or calyx,	″ 3—Monogynia, Di.-Pentagynia, and Polygynia.
13. Polyandria, ″ 20 or more	″ , on the receptacle, .	″ 6—Mono., Di., Tri., Tetra., Pentagynia, and Polygynia.
14. Didynamia, ...	4 ″ , 2 long and 2 short, .	″ 2—Gymnospermæ and Angiospermæ.
15. Tetradynamia, . . .	6 ″ , 4 long and 2 short,	″ 2—Siliculosa and Siliquosa.
16. Monadelphia, all the filaments united, ...		″ 8—Tri., Pent., Hex., Hept., Oct., Dec., Dodec., and Polyand.
17. Diadelphia, filaments united into two sets, ...		″ 4—Pentandria, Hexandria, Octandria, and Decandria.
18. Polyadelphia, filaments in three or more sets, ...		″ 2—Decandria and Polyandria.
19. Syngenesia, five stamens united by their anthers, . . .		″ 5—Polyg.-Æqualis, Superfl., Necess., Frustranea, Segregata.
20. Gynandria, the stamens growing on the pistil, ...		″ 3—Monandria, Diandria, and Hexandria.
21. Monœcia, flowers with stam., others with pist. on same plant,		″ 10—Mona., Di., Tri., Tet., Pen., Hex., Oct., Icos., Polyan., Monadelphia.
22. Diœcia, stamens on one plant, and pistils on another, .		″ 13—Mo., Di., Tr., Tet., Pen., Hex., Oc., En., Dec., Do., Ic., Polyand., and Monadelphia.
23. Polygamia, unisex. or bisex. flowers on same or diff. plants,		″ 2—Monœcia, Diœcia.
24. Cryptogamia—inconspicuous flowers, ...		″ 5—Filices, Musci, Lichenes, Fungi, Algæ.

I. MONANDRIA.—The first order of this class contains many highly ornamental exotics, chiefly reed-looking herbaceous plants, with large leaves and showy flowers. The seeds and roots of many of these are used in medicine as well as by the dyer—as tumeric, arrow-root, and *Zingiber officinale*, the common ginger of commerce. Their predominating qualities are aromatic. Several of the genera are British—as hippuris, glass-wort, &c. The second order, DIGYNIA, contains *Callitriche*, the water-starwort, frequently met with in our ditches. There is another plant, sometimes sown in borders as an ornamental annual, which also belongs to it—namely, *Blitum capitatum*, the strawberry blite.



Digynia. Monogynia.

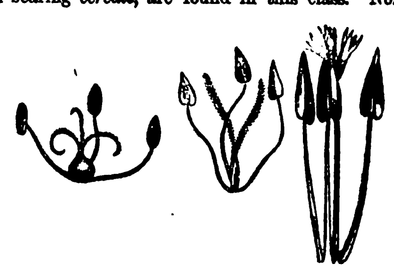
II. DIANDRIA.—Flowers with two stamens, and with



Trigynia. Digynia. Monogynia.

one, two, or three pistils; thus constituting three orders, of which there are upwards of sixty genera. The first order, MONOGYNIA, contains by far the greater number of the genera. Here we find the useful olive, the fragrant jasmine, the lilac, and many evergreen shrubs. Nor are the herbaceous members of the order less prized: the wild and cultivated speedwells, and the elegant slipper-wort, are among the choicest gifts of Flora. The rosemary, and the numerous species of sage, are ranked in this order, though some botanists have suggested the removal of the latter plant to the class DIDYNAMIA, because, in addition to the two perfect stamens, there are the rudiments of two others in the flower.

III. TRIANDRIA.—Almost all the grasses, including the grain-bearing *cereals*, are found in this class. Nor are

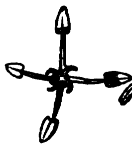


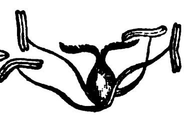
Trigynia. Digynia. Monogynia.

the other genera less remarkable for the beauty of their flowers, than are the grasses and cereals for their

usefulness. The well-known crocus, the corn-flag, and iris, and many allied foreign genera, are among the chief ornaments of our gardens, thus compensating in some measure for their want of usefulness when compared with their associates the cereals.

IV. Tetrandria.—Flowers with four stamens *of equal length*. The equal length of the stamen should be specially kept in mind, because the fourteenth class (Didynamia) has also four stamens, but of these two are longer than the others. Many of the genera of this class are beautiful shrubs and trees, chiefly natives of the Cape of Good Hope and New Holland—as the *Proteas*, *Hakias*, *Banksias*, and the splendid waratah or *Telopia speciosissima*. Several fine ornamental exotics—as the *Ixoras*, for instance—belong to this class, as well as many hardy plants, both shrubs and herbs, natives of Europe, such as *Buffonia tenuifolia*—named after the

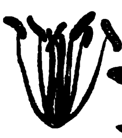

Tetragynia.


Digynia.

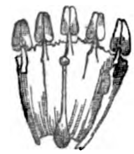

Monogynia.

celebrated naturalist Count de Buffon—the witch-hazel, a hardy North American tree; the well-known holly, which as a hedge-plant and ornamental evergreen is unrivalled, and whose timber, when it has attained full size, is solid, white, and of remarkably fine grain, and much used by musical instrument-makers and other artists. The common pond-weeds (*Potamogeton*), so frequent in our slow-running rivers, also belong to this class.

V. Pentandria.—Here we find the *Asclepias*, with its curiously constructed flowers, and the no less remarkable *Stapelia*, a family of plants, bearing flowers of uncommon character both in shape and colour, and moreover


Trigynia.


Digynia.


Monogynia.

diffusing a scent so loathsome, that blow-flies lay their eggs on the petals! Here also we find the remarkable English parasitical plant, the dodder (*Cuscuta Europæa*), and the stately elm-tree, so useful both for ornament and timber; the ornamental laurustine, the elder, and other well-known plants. The sumach family, so variously useful in the arts, is also ranked here; the beautiful Grass of Parnassus, so common in our marshes; the pansy, the primrose, forget-me-not, and other plants; but we can only add the names of one or two more, such as the highly ornamental family of *Crassula*, a tribe of succulents chiefly from the Cape of Good Hope; the superlatively useful flax; the neat thrift, used for the edgings of walks in gardens; the *Myosurus minimus*, or mouse-tail, &c.


Pentagynia.

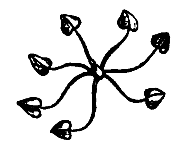

Tetragynia.

VI. Hexandria.—Flowers with six stamens of *equal length*. By far the greater number of our bulbous flowering and culinary plants—as the narcissus, the lilies, the long-lived American aloe, the magnificent Crinum and Pancratium, the unequalled fruit of the pine-apple, and the equally useful onion, asparagus, &c.—belong to this class. The plants are chiefly herbaceous, and are found in every clime from the torrid to the arctic zone, in the burning sands of Africa, and amid the snows of Siberia. One of them (rice) is most important to the inhabitants of tropical countries, and to those of the warmer parts of the temperate zones. It is the staff of life in India, and is cultivated on every spot of level ground where there is a command of water for irrigation. Here also we have the elegant Trillium, the meadow saffron, and the water-plantain.


Digynia.

VII. Heptandria.—This class is illustrated by the *Æsculus* and *Pavia*, better known by the name horse-chestnuts. They are among the most ornamental of our forest-trees, though they are not natives. The flowers of the common sort are well known; one or two of the pavias have bright red flowers, and are most striking objects in ornamental scenery. The common horse-chestnut yields great crops of nuts, which are used for the food of some domestic animals. It is remarkable that among above 3000 genera, only one should occur with seven stamens and seven styles; indeed, as Rousseau remarks, nature has neglected the number seven in her arrangement of vegetable structures.


Digynia.

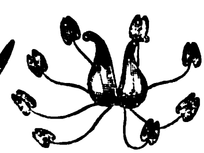

Monogynia.


Heptagynia.


Tetragynia.

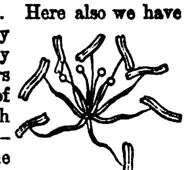
VIII. Octandria.—The heaths are the most conspicuous and numerous examples of the class. Of this family alone there are 543 species already described, chiefly natives of the southern parts of Africa. A few are found in Britain, and several in other parts of Europe. The curious *Rhexia*, the day and night flowering *Œnothera*, and the elegant *Fuchsia*, are found in this class; so also is the well-known *Mezereon*, and


Trigynia.

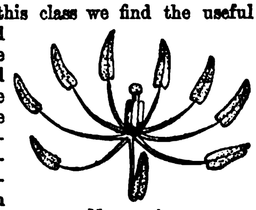

Digynia.


Monogynia.

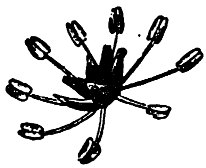
many exotic genera of great beauty. Here also we have the sea-side grape, and soapberry of the West Indies; the curiously organised *Bryophyllum*, which bears viviparous progeny on the edges of its leaves, in addition to those which are yielded by the perfect seeds—a remarkable departure from the usual way in which plants produce viviparous offspring.

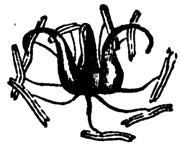

Tetragynia.

IX. Enneandria.—In this class we find the useful and fragrant cinnamon, and the famous laurel, whence so many medicinal oils and other useful substances are extracted; as well as the excellent medical and culinary rhubarb; the flowering rush of Britain (*Butomus umbellatus*), which is common in ponds and ditches in a few localities in this country, and is one of


Monogynia.

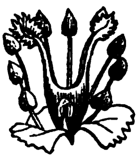
our most showy wild plants. The leaves are partly under and partly above water. The flower-stalk is


Hexagynia.


Trigynia.

elevated a few feet in the air, and bears an umbel or tuft of very beautiful flowers, which are pale and tinged with pink or blush colour, or frequently entirely purple.

X. Decandria.—Many of the species of this class are brilliantly flowering shrubs; we have the *Kalmias*, *Ledums*, *Rhododendrons*, *Andromedas*, &c., plants as generally admired as they are universally cultivated: we have also the arbutus, the fine aromatic-scented storax-tree, and many other exotics of the greatest beauty; the *Hydrangea*, the extensive genus *Saxifraga*, and the equally extensive family of *Dianthus*, which includes the carnation, pink, sweet-william, and other species and varieties of that favourite tribe. The catchflies, stitchworts, and sandworts, are all found here; as


Digynia.

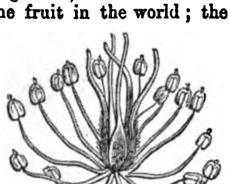

Decagynia.

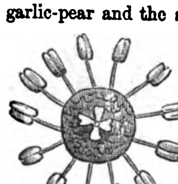

Pentagynia.


Trigynia.

also the *Cotyledons* and the *Oxalises* of the Cape of Good Hope; the *Sedums* of Europe; the lychnis, mouse-ear, chickweed, the common spurrey, and *Phytolacca*.

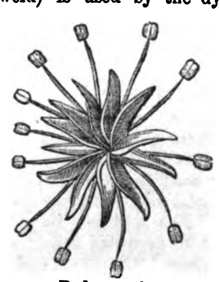
XI. Dodecandria.—There is no plant yet discovered with eleven stamens, and all those of this class have the number varying from twelve to nineteen. The class, among many fine tropical plants, includes the celebrated mangosteen, said to be the most delicious and wholesome fruit in the world; the garlic-pear and the showy


Pentagynia.


Tetragynia.

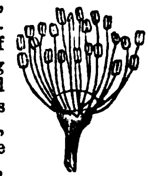
British plant which ornaments the banks of our rivers in some parts of the country during summer, the *Lythrum Salicaria;* agrimony, common on road-sides; and *Reseda*, one species of which (weld) is used by the dyer for


Monogynia.

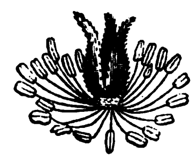

Dodecagynia.

producing a yellow colour; while another, *R. odorata*, is the universal favourite, mignonette, cultivated entirely for its scent. The extensive *Euphorbia* or *Spurge* family also belongs to this class, and the curious *Sempervivum*, or house-leek, as well as the still more remarkable *Cephalotus*, whose leaves are formed into elegant pitchers, furnished with lids, like those of the *Nepenthes*, or pitcher-plant.

XII. Icosandria.—Flowers having twenty or more stamens seated upon the corolla or calyx. The situation, and not the number of the stamens, furnishes the characters of the class. This is one of the most important of the Linnæan classes, as containing many of our most useful fruits, as well as most esteemed flowers, such as the roses, the gorgeous Cactal genera, *Cereus*, *Epiphyllum*, and *Opuntia;* the myrtle, and its allied genera, *Eugenia*, and *Eucalyptus*. Of fruits we have the guava, pomegranate, pear, apple, quince, strawberry, raspberry, &c. Of the extensive genus *Mesembryanthemum*, there are many hundred species.

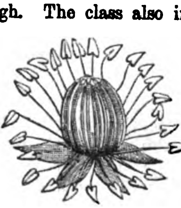

Monogynia.

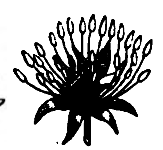
XIII. Polyandria.—Flowers having an unlimited number of stamens, distinct from each other, and seated on the receptacle. This class comprises, among many others, the caper-tree, the well-known poppy, the curious sarracenia, and the magnificent water-lily. To this class also belongs the *Bixa orellana*, the red pulp of which is extensively used by dyers under the name of arnotto;


Trigynia.


Monogynia.

the splendid peony, the beautiful larkspurs, the dangerous aconite, and the butter-nut, a pleasant cooling tropical fruit, which is beginning to become known in Britain, being now offered for sale in the shops in Liverpool and Edinburgh. The class also includes a great many fine

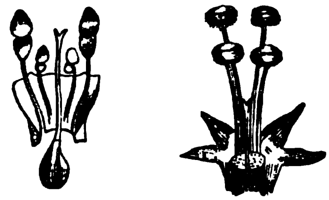

Polygynia.


Pentagynia.

flowering-plants, both shrubs and herbs: among the former, the magnolia is most conspicuous; among the latter, the columbine, anemone, and ranunculus. Of early or winter flowering-plants, the aconite and hellebore are examples, and the globe-flower and marsh-marigold are showy plants.

XIV. Didynamia.—The flowers of this class are generally ringent; they have four stamens, *two of which are longer than the others*. The flowers of the fourth class have also four stamens, but these are of equal lengths; while in this, two are long and two short. The calyx also is of one leaf, and tubular, divided into five or two lipped segments, which are unequal and persistent. The corolla is of one petal; the upper lip concave, and sometimes bifid; the lower lip trifid. In the first order, the so-called Gymnospermæ, we find the germander, lavender, mint, and dead-nettle, and many others of similar character: several of them are useful in cookery. The order Angiospermæ, so called because, though the stamens are the same in number and position, the seeds are differently disposed, being contained in a more evident capsule than the preceding. Many of the plants in this

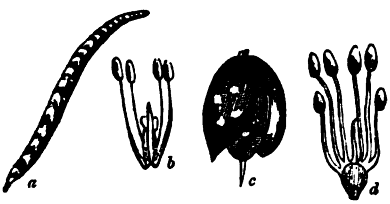
order are very beautiful; for instance, the bignonia, antirrhinum, mimulus, &c. The common foxglove



Angiospermæ. Gymnospermæ.

(*Digitalis purpurea*), so conspicuous on our hedge-banks, also belongs to this order.

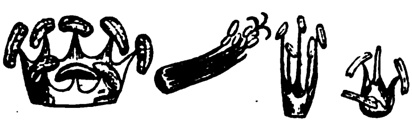
XV. TETRADYNAMIA.—Flowers with six stamens, four of which are longer than the other two. Linnæus divided this class into two orders—SILICULOSÆ and SILIQUOSÆ—the former being a short roundish pod (*c*), and the latter a long one (*a*). Many of the plants are dietetic—as the cabbage, turnip, radish, &c.; and some are finely scented and favourite flowers—as the wallflower, stock, rocket, &c. The seeds of several cruciferous plants yield oil of excellent quality. This is a truly natural class of plants, forming the *Cruciferæ* of Jussieu; great similarity of the flowers, seeds, &c., being observable throughout the whole of the genera. The calyx is four-leaved, sepals



Stamens and Seed-vessels.

concave, equal, and deciduous; corolla of four petals, claws inserted into the receptacle, limbs widening outwards in a cruciform manner.

XVI. MONADELPHIA.—The stamens are united into one set in this class, which is divided into eight orders, founded on the number of the stamens, not on that of



Octandria. Heptandria. Pentandria. Triandria.

the pistils, as in other classes. In the first order, TRIANDRIA, we find several beautiful Cape bulbs—as the *Tigridia*, *Herbertia*, &c. The flowers are not only of uncommon forms, but curiously spotted or streaked with dark colours. Of the second order, PENTANDRIA, the passion-flower is the most remarkable. There is also the *Erodium* or heron's-bill, a section of plants allied to the geraniums. The third order, HEXANDRIA, contains but one genus, a bulbous-rooted plant, called *Gilliesia graminea*, having grass-like leaves and curious flowers. The fourth order, HEPTANDRIA, contains the pelargoniums, commonly called geraniums—a genus of plants unequalled for immense variety of forms and colours. They are chiefly natives of the Cape of Good Hope. The fifth order, OCTANDRIA, having eight stamens, united in one set, contains the genus *Aitonia*, named by Linnæus in honour of the late William Aiton, Esq., royal gardener at Kew. In the sixth order, DECANDRIA, we find the true geraniums or crane's-bills, chiefly herbaceous plants, found in many parts of the temperate latitudes. The seventh order, DODECANDRIA, are all tropical plants. In the eighth order, POLYANDRIA, are many of our gayest flowering-plants—as the althea,

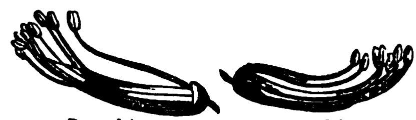
Polyandria. Dodecandria. Decandria.

lavatera, hibiscus, sida, silk cotton-tree, the tea-tree, and its magnificent congener, the camellia.

XVII. DIADELPHIA.—Flowers having two sets or brotherhoods of stamens. In general, nine are united

Hexandria. Pentandria.

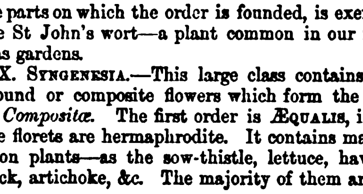
together, with a single one by itself, which is accounted the second brotherhood. Examples: *Monniera trifolia*,



Decandria. Octandria.

an African annual of no great beauty; *Fumaria*, fumitory; and *Polygala*, the milkwort; and leguminous plants. These are showy plants of curiously constructed flowers, called *papilionaceous*, or butterfly shaped; their seed-vessels being pods, such as the common furze, broom, genista, laburnum, restharrow, lupine, and many other beautiful plants, as well as trees, shrubs, and herbs.

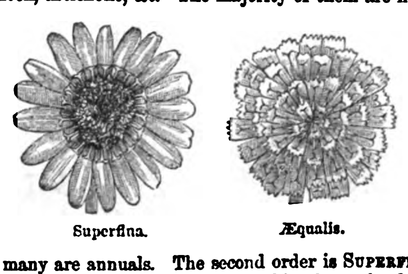
XVIII. POLYADELPHIA.—This class contains all plants whose flowers have their stamens arranged in many brotherhoods. Among the plants of this class we find the *Theobroma*, which yields chocolate. This disposition



Polyandria. Decandria.

of the parts on which the order is founded, is exemplified in the St John's wort—a plant common in our fields as well as gardens.

XIX. SYNGENESIA.—This large class contains all the compound or composite flowers which form the natural order *Compositæ*. The first order is ÆQUALIS, in which all the florets are hermaphrodite. It contains many very common plants—as the sow-thistle, lettuce, hawkweed, burdock, artichoke, &c. The majority of them are herbs,



Superflua. Æqualis.

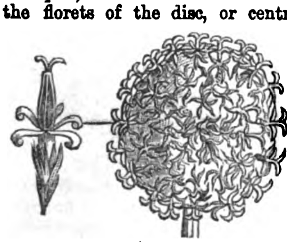
and many are annuals. The second order is SUPERFLUA; here we find plants, the flowers of which have the florets

of the disc bisexual, and those forming the rays female. This is also a very large order, and contains many useful as well as beautiful plants, of which tansy and chamomile, helichrysiums, xeranthemums, dahlias, &c., are examples. The third order is FRUSTRANEA, so called because the florets of the disc are bisexual, and those in the ray or margin neuter. To this belongs the splendid sunflower, with which many of the same style of flowering-plants are arranged, such as the rudbeckia,

Necessaria.

Frustranea.

coreopsis, &c. The fourth order is NECESSARIA, because the florets of the disc, or centre of the flower, being all male, it is necessary that those of the ray or margin should be female, in order that there may be perfect seed produced. Example: Calendula. The fifth order is called SEGREGATA, because the florets have each its proper involucre. All the plants in this order are exotic herbs and under-shrubs, the globe-thistle being the most common in British gardens.



Segregata.

XX. GYNANDRIA.—This class contains plants which have their stamens seated upon the pistil; they are generally herbaceous, with tuberous roots, curious gouty or climbing stems; many are epiphytes growing on trees.

Hexandria. Diandria. Monandria.

The class is divided into three orders; the first, MONANDRIA, having one anther seated on the pistil, and comprises orchis, ophrys, epipactis, &c. In the second order, DIANDRIA, the flowers have two anthers on the pistil; to this belongs the ladies-slipper, a great rarity found in damp woods, particularly in the north of England. The third order, HEXANDRIA, containing plants which have six stamens seated in the pistil, has only one genus—namely, the *Aristolochia*, or birthwort.

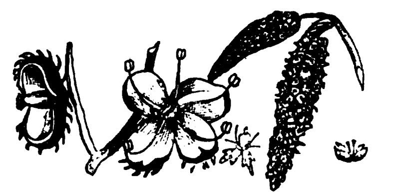
XXI. MONŒCIA.—This class consists of plants which

Diandria.

Monandria.

have male and female flowers separate, but on the same root—such as the celebrated bread-fruit tree, the *Zannichellia palustris*, the maize or Indian corn (*Zea*), the box and mulberry, the common nettle, the well-known foreigner *Aucuba japonica*, the amaranthus, the coco-nut, and other palms, *Begonia*, the chestnut, beech, hazel, walnut, oak, pines and firs, larch, cedar, cypress, &c. Here are also the gourd, melon, and cucumber, the poisonous manihot, and the castor-oil. There are ten orders, distinguished by the number and arrangement of the stamens, &c., some of which are illustrated in the wood-cuts. To this class belong the *Carices*, which form so important a feature in the Floras of cold countries, and also the *Eriocaulon septangulare*, which is interesting in a botanico-geographical point of view, inasmuch as it represents in the Western Isles of Scotland a genus which prevails on the American continent. Of *Zannichellia*, it may be observed that it would form an interesting plant for a fresh-water aquarium; and certainly no other aquatic genus requires more careful elucidation with respect

Triandria.



Pentandria. Tetrandria.

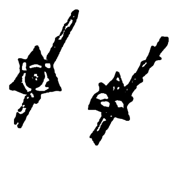
Polyandria. Hexandria.

Monadelphia.

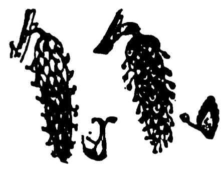
to its species. Since this sheet was in type, we have received from Benares a beautiful plant covered with large clusters of the curiously crested fruit of this genus; it appears to be an undescribed species, and has received the provisional name of *Zannichellia Spottiswoodiana*.

XXII. DIŒCIA.—This class is composed of plants which have unisexual flowers, not on the same, but on different individuals, such as the remarkable screw-pine: so called because the leaves resemble those of the pine-apple, although much larger, and they issue from the stem in a very different manner; that is, neither opposite nor alternately, but the last always a little to the left of the former, so that they are expanded spirally like the worm of a screw. Here also we have the willow,

crow-berry, date-palm, candle-berry myrtle, sweet gale, spinach, misletoe, stratiotes, &c. The orders are distinguished by the number, &c., of the stamens, as indicated in the following wood-cuts :—



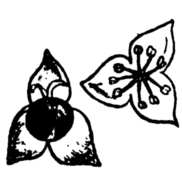
Triandria.



Monandria.

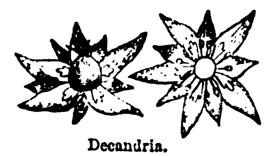
Hexandria.

Pentandria.

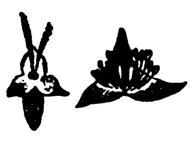


Enneandria.

Octandria.

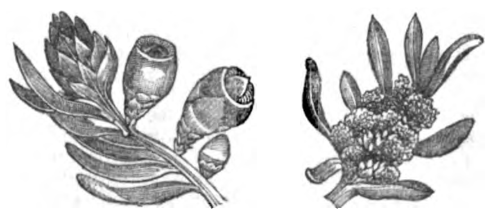


Decandria.



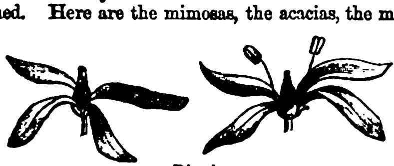
Polyandria.

Icosandria.



Monadelphia.

XXIII. Polygamia.—The class Polygamia (a word signifying many marriages) is composed of plants having both unisexual and bisexual flowers on the same or on different roots. There is considerable uncertainty about the arrangement of this division, because some of the genera are not always constant in their modes of flowering; and even single plants will occasionally exhibit all the characters by which the different orders are distinguished. Here are the mimosas, the acacias, the maples,



Diœcia.

the beautiful Ailantus, the mango, many grasses, the ash—so useful for its timber—the bread-nut, the anacardium, and figs.

XXIV. Cryptogamia.—The class Cryptogamia (a term signifying hidden marriages) consists of the flowerless plants corresponding with the class of the same name in the natural system, to which reference may be made for further particulars.

THE NATURAL SYSTEM.

'The Natural System of Botany,' says Dr Lindley, 'being founded on these principles—that all points of resemblance between the various parts, properties, and qualities of plants shall be taken into consideration; that thence an arrangement shall be deduced in which plants must be placed next each other which have the greatest degree of similarity in these respects; and that consequently the quality of an imperfectly known plant may be judged of by that of another which is well known—it must be obvious that such a method possesses great superiority over artificial systems, like that of Linnæus, in which there is no combination of ideas, but which are mere collections of isolated facts, having no distinct relation to each other. The advantages of the Natural System, in applying botany to useful purposes, are immense, especially to medical men, who depend so much upon the vegetable kingdom for their remedial agents. A knowledge of the properties of one plant enables the practitioner to judge scientifically of the qualities of other plants naturally allied to it; and therefore the physician acquainted with the natural system of botany may direct his inquiries, when on foreign stations, not empirically, but upon fixed principles, into the qualities of the medicinal plants which have been provided in every region for the alleviation of the maladies peculiar to it. He is thus enabled to read the hidden characters with which Nature has labelled all the hosts of species which spring from her teeming bosom. Every one of these bears inscribed upon it the uses to which it may be applied, the dangers to be apprehended from it, or the virtues with which it has been endowed. The language in which they are written is not indeed human: it is in the living hieroglyphics of the Almighty, which the skill of man is permitted to interpret. The key to their meaning lies enveloped in the folds of the natural system, and is to be found in no other place.' Such a system as is here eloquently delineated, we aim at rather than possess. All the modifications—and they are neither few nor unimportant—of Jussieu's original plan which have been promulgated, are merely contributions to one great end; and years of patient research, crowned by the most extensive powers of generalisation, must elapse before botany can boast of a perfect system. Passing, then, numerous recent suggestions, British and continental, we shall adhere in our brief exposition to a simple modification of the natural system which seems most applicable to botanical works now in current circulation.

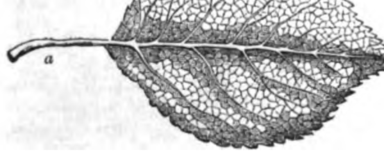
According to the original system of Jussieu, all the known plants were arranged into a hundred Orders, beginning with the *Fungi*, and mounting upwards to the *Coniferæ;* and these Orders were divided into three great Classes—namely, the ACOTYLEDONES, or plants without any cotyledon in the seed; the MONOCOTYLEDONES, plants with one cotyledon; and the DICOTYLEDONES, those with two or more cotyledons. The Acotyledonous plants were not subdivided; but the Monocotyledones were arranged into sub-classes, according as the stamens were *hypogynous*, or arising from under the pistil; *perigynous*, or growing from the calyx; and *epigynous*, or arising apparently from above the ovary by adhesion to it. The Dicotyledones were divided into the *apetalous*, or those without petals; the *monopetalous*, those with one petal; and the *polypetalous*, those with several petals; and these again were subdivided, according to the position of the stamens with regard to the pistil, in the same manner as the Monocotyledonous plants. To these were added what Jussieu called *Diclines*, or those plants with separated unisexual flowers. The fault of this system, like that of Linnæus, was that it associated species dissimilar in their nature; the classification depending on one peculiar feature more than on the general appearance, qualities, and habits of the plant.

The system of Jussieu was improved by Decandolle, who at first made 161 Orders; but these were afterwards greatly increased, and Lindley now enumerates upwards of 300.

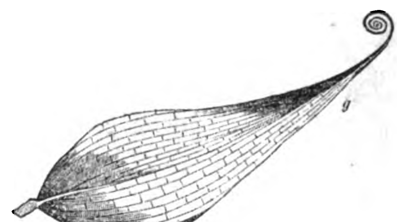
The first grand division of De Candolle, like that of Linnæus, is into the Flowering and Flowerless plants, which he designates respectively the *Vasculares* and the *Cellulares*. This division, however, is not absolutely correct; for although all the flowering-plants contain vascular tissue, and the flowerless consist principally of cellular tissue, yet spiral vessels and ducts are common in the ferns and club-mosses. The *Vasculares* and *Cellulares* of De Candolle may be considered as equivalent to the *Phænogamia* and *Cryptogamia* of the older botanists.

His second division depends upon the cotyledons of the embryo; and, like Jussieu, he divides the flowering-plants into DICOTYLEDONES, or those with two or more

cotyledons or seed-leaves, as *a*; MONOCOTYLEDONES, those which have only one seed-leaf (*b*, *b*); and ACOTYLEDONES, those having no seed-leaf, and, in fact, no seeds—such as the Cryptogamia. The differences between these three divisions are decided, and are exhibited in different parts of the plant; but they are particularly conspicuous in the leaves—the venation of Dicotyledonous

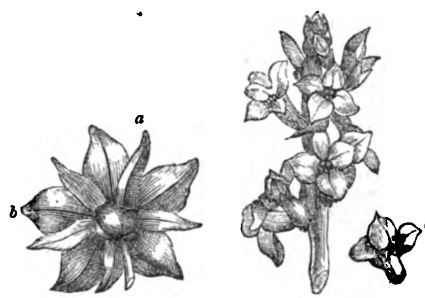


leaves being reticulated, as in the apple (*a*); and that of Monocotyledonous being chiefly in parallel lines, as shewn in the leaf of the Gloriosa (*g*). Dicotyledonous trees are said to be *Exogenous*, from the fact of their



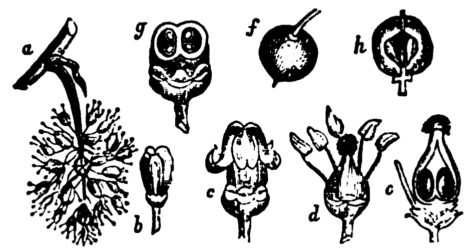
trunks increasing by external layers; Monocotyledonous ones, *Endogenous*, on account of the enlargement taking place from within; and Acotyledonous trees, *Acrogenous*, because the increase takes place only at the top or growing-point.

Dicotyledonous plants are divided into the *Dichlamydeæ*, or those with two floral envelopes—that is, having



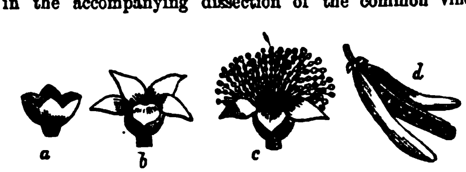
a separate calyx (*a*) and corolla (*b*); and the *Monochlamydeæ*, or those having only one floral envelope, which is always called the calyx, as in the detached floret in the wood-cut (*c*). These distinctions, however, are not always invariable, as many plants in the first division have no corolla, but simply a coloured calyx.

The *Dichlamydeæ* are further divided into three sub-classes:—I. *Thalamifloræ*, in which the stamens and



Vine.—*a*, bunch of flowers; *b*, flower before expansion; *c*, flower expanding; *d*, stamens and ovary; *e*, vertical section of the ovary; *f*, fruit; *g*, horizontal section of the ovary; *h*, vertical section of the fruit, shewing the position of the seed.

petals are all inserted in the receptacle, as represented in the accompanying dissection of the common vine.



Acacia.—*a*, calyx; *b*, corolla; *c*, flower; *d*, seed-pod open.

II. *Calyciforæ*, in which the stamens and petals are

perigynous, inserted in the calyx, as shewn in the preceding dissection of an acacia; or epigynous, arising from the upper part of the ovary. III. *Corolliflorœ*, in which the stamens are inserted on the petals, as in the annexed dissection of the acanthus, or in a few cases on the

Acanthus.—*a*, corolla opened, shewing the stamens and pistil; *b*, one stamen; *c*, pistil; *d*, ripe seed-vessel, covered with its calyx and bracts; *e*, seed-vessel burst previously to shedding its seeds; *f*, seed opened, shewing the radicle and plume.

receptacle, the parts of the corolla being united together. The *Monochlamydeœ* are those having only one floral envelope.

Monocotyledonous plants are divided into those with petals, called *Petaloideœ*, and those with glumes, like the oat, *Glumiferœ*.

Flowerless or *Cryptogamous* plants are divided into two classes—those formed of a cellular expansion without distinct stem or leaves, which are called *Thallogens* (*a*); and those with leaves borne upon a distinct stem, *Acrogens*.

Cryptogamous plants.

The distinctions between the orders are drawn from the number and arrangement of petals, sepals, and stamens; the construction of the anthers, and the manner in which they burst; the structure of the seed-vessel and of the seeds, with the position of the embryo; the position of the leaves, whether alternate or opposite, or with or without stipules; and the general habits and properties of the plants.

Having thus explained the basis of arrangement, we shall now proceed to consider the ORDERS—premising that while the whole are tabulated, our space will only permit us to detail the more interesting and important ones. This, however, we shall endeavour to do in such a manner as may at once present an outline of the System, and render the reader familiar with the phraseology and plan of procedure.

In this and the subsequent lists of natural orders, those orders marked with an asterisk contain British representatives.

DICOTYLEDONOUS PLANTS.—DICHLAMYDEÆ.

§ THALAMIFLORÆ.

*Ranunculaceæ—Crowfoots.
Dilleniaceæ—Dilleniads.
Magnoliaceæ—Magnoliads.
Anonaceæ—Anonads.
Schizandraceæ—Schizandra order.
Menispermaceæ—Moonseeds.
Lardizabalaceæ—Lardizabala order.
*Berberidaceæ—Berberids.
Cabombaceæ—Watershields.
*Nymphæaceæ—Water-lilies.
Nelumbiaceæ—Water-beans.
Sarraceniaceæ—Sarraceniads.
*Papaveraceæ—Poppyworts.
*Fumariaceæ—Fumeworts.
*Cruciferæ—Crucifers.
Capparidaceæ—Capparids.
*Resedaceæ—Weldworts.
Flacourtiaceæ—Bixads.
*Cistaceæ—Rock-roses.
*Violaceæ—Violets.
*Droseraceæ—Sun-dews.
*Polygalaceæ—Milkworts.
Krameriaceæ—Rhatany order.
Tremandraceæ—Poreworts.
*Tamaricaceæ—Tamarisks.
*Frankeniaceæ—Frankeniads.
*Elatinaceæ—Water-peppers.
*Caryophyllaceæ—Cloveworts.
Vivianiaceæ—Vivania order.
*Malvaceæ—Mallowworts.
Sterculiaceæ—Silk-cottons.
Byttneriaceæ—Byttneriads.
*Tiliaceæ—Lindenblooms.
Dipteraceæ—Dipterads.
Chlænaceæ—Chlænads.
Ternströmiaceæ—Theads.
Olacaceæ—Olacads.
Icacinaceæ—Icacina order.
Cyrillaceæ—Cyrilla order.
Aurantiaceæ—Citronworts.
*Hypericaceæ—Tutsans.
Guttiferæ—Guttifers.
Marcgraviaceæ—Margraviads.
Hippocrateaceæ—Hippocrateads.
Malpighiaceæ—Malpighiads.
Erythroxyleæ—Redwoods.
*Aceraceæ—Maples.
Sapindaceæ—Soapworts.
Rhizobolaceæ—Rhizobols.
Meliaceæ—Meliads.
Humiriaceæ—Humirium order.
Cedrelaceæ—Cedrelads.
Vitaceæ—Vineworts.
*Geraniaceæ—Cranes-bills.
*Linaceæ—Flaxworts.
*Oxalidaceæ—Oxalids.
*Balsaminaceæ—Balsams.
Tropæolaceæ—Indian Cresses.
Limnanthaceæ—Limnanths.
Pittosporaceæ—Pittosporum order.
Brexiaceæ—Brexia order.
Zygophyllaceæ—Bean-capers.
Rutaceæ—Rueworts.
Xanthoxylaceæ—Prickly-ash order.
Ochnaceæ—Ochnads.
Simarubaceæ—Quassiads.

RANUNCULACEÆ.—The plants constituting this order are herbs, or rarely shrubs, with deeply cut, rarely stipulate leaves, and stem-clasping petioles. The majority of the species are hardy, and abound in an acrid poisonous juice, as is well exemplified in the common butter-cups of the meadows belonging to the genus *Ranunculus*, from which the order takes its name. The plants of the order are very variable in their flowers; many of them having merely one floral envelope, and others having a coloured calyx, with only very small and inconspicuous petals. When the flowers are regular—that is, when the parts are all of one size—the corolla consists generally of five petals, and the calyx of five sepals, though the number of the petals sometimes varies from three to fifteen. There are numerous stamens which grow from beneath the pistil, and are always separate, having their anthers bursting outwardly. The seeds are for the most part contained in carpels which grow close together. The embryo is very small, and placed at the base of the albumen, which is either fleshy or bony. In consequence of the variable character of their flowers, the Ranunculaceæ are somewhat perplexing to the learner, though they may be generally known by their numerous distinct stamens springing from below the pistil, and by their distinct carpels, which frequently grow in several whorls round an elevated receptacle, as in the crowfoot and *Flos Adonis*. The calyx generally falls off with the petals, but in the peony it remains till the seed is ripe. The carpels are in many cases only one-seeded, and are sometimes winged, as in the anemone and clematis, in order to scatter the seeds, as the carpels in this case do not open naturally, but fall with the seed. Sometimes, however, the carpels are many-seeded, and open naturally when ripe, as in the peony, the larkspur, the columbine, &c. The principal genera—which lie within the examination of every one—are the Ranunculus and Peony, having regular flowers and two floral envelopes; the Anemone, the Hepatica, the Christmas Rose, and the winter Aconite, which have regular flowers, but generally only one floral envelope; and the Larkspur, Monkshood, and Columbine, which have irregular flowers. The Clematis is one of the few shrubby plants belonging to the order; it has regular flowers, and generally only one floral envelope. The Ranunculaceæ are of little

economical importance. The juice of the whole order is acrid, the roots of many intensely bitter, and the bark of a few tonic and bitter. The seeds of the Nigella are aromatic, and were formerly used as pepper; but those of all the other genera are poisonous, unless husked. The flowers of some are objects of great beauty—as the larkspurs, ranunculuses, anemones, peony, and columbine. The 'lesser celandine' of Wordsworth (*Ranunculus Ficaria*) has been used as an article of food in Austria, its small farinaceous tubers resembling pease. But most of the plants belonging to the order are acrid and poisonous, some of them eminently so. *Ranunculus arvensis* is one of the most dangerous farm-weeds which the agriculturist has to fear; but the monkshood (*Aconitum Napellus*) exceeds them all in virulence, and has been the cause of distressing accidents, from its root being mistaken for horse-radish, &c. We read in classic story how the Roman stepmothers of old employed this root to poison their adopted children; and a nearly allied species has derived notoriety from having been employed by the Nepalese to poison their wells against the approach of an enemy. According to Mr Herapath, the poisonous alkaloid of the monkshood (Aconitine) is the most deadly poison known.

DILLENIACEÆ.—This order consists of woody plants, having astringent qualities. Some of them yield excellent timber. They are chiefly confined to Australasia, India, and equinoctial America.

MAGNOLIACEÆ.—This order consists of woody plants, remarkable for the beauty of their flowers and foliage, of which the common magnolia of gardens is a familiar example: they have bitter, tonic, and aromatic qualities. The New Holland tree called *Tasmannia aromatica*, supplies a substitute for pepper, Winter's Bark is yielded by *Drimys*, and the tulip-tree of North America is the *Liriodendron tulipifera*. The wood of *Illicium* and *Drimys* exhibits under the microscope an appearance of discs slightly resembling those of Coniferæ.

ANONACEÆ.—Woody plants, chiefly natives of the tropical regions. The sweetsop, soursop, and custard-apple, are yielded by species of *Anona*. The lance-wood used by coachmakers is supposed to be yielded by another plant of this order (*Duguetia quitarensis*).

SCHIZANDRACEÆ.—The plants of this order are chiefly trailing tropical shrubs, abounding in an insipid mucus. The fruit of some is eatable, but the order is otherwise unimportant.

MENISPERMACEÆ.—Trailing herbs or shrubs, climbing to the tops of the highest trees in hot countries, their stems formed by peculiar woody wedges. *Cocculus Indicus*, a dangerous substance, which appears to be extensively employed in the adulteration of malt liquors—chiefly the cheaper sorts—consists of the berries of *Anamirta paniculata*, a plant of this order which abounds on the Malabar coast and in the Indian Archipelago. Its use for such purposes is forbidden by act of parliament; but as 2359 hundredweights were imported into Britain in 1850, it appears pretty certain that it finds other uses than that of medicine. The bitter tonic calumba root is derived from *Jateorrhiza palmata*.

LARDIZABALACEÆ.—An unimportant order, consisting of fifteen twining shrubs, which are distributed over the cooler parts of South America and China; the fruits of some are eatable.

BERBERIDACEÆ. — Plants of temperate and warm countries in both hemispheres, represented in Britain by the common barberry of our hedgerows, the stamens of which display the phenomenon of irritability when touched near the base by the point of a pin. According to Professor Simpson, the roots of several species furnish the astringent matter called Lycium by Dioscorides.

CABOMBACEÆ consists of three aquatic plants, with floating peltate leaves, occurring in America and New Holland.

NYMPHÆACEÆ.—Gigantic aquatic herbs, with a thick rhizome in the mud, giving off large floating leaves on long petioles. The rhizomes exhibit a structure resembling that of endogenous plants; but the embryo is truly dicotyledonous. Water-lilies appear to occur in most parts of the world, except cold regions. The white water-lily (*Nymphæa alba*) is one of the greatest ornaments of the English and Scotch lakes; while the yellow one (*Nuphar lutea*) more commonly occurs in slow streams and pools. *N. pumila* is rare. More magnificent than all is the *Victoria regia*, the royal water-lily of South America, whose size, in keeping with the gigantic proportions of the Amazons and Essequibos, on whose waters it displays its beauty, is unrivalled in the vegetable kingdom. Its floating leaves are two yards across, continuously covering miles of surface with their verdure, each having a turned-up margin like a tea-tray. The flowers are a foot across, formed of hundreds of petals of the most delicate rose-colour, and exhale a delicious perfume in the evening as they expand. This plant has been successfully cultivated in the public gardens of London, Belfast, Glasgow, &c.

NELUMBIACEÆ.—This order, consisting of the Water-beans of the tropics, is chiefly remarkable, in a structural point of view, on account of the large torus, in which the nuts are half buried, resembling the rose of a watering-pan. *Nelumbium speciosum* is that 'mythic lotus'—the 'holy and beautiful plant'—which is sculptured on the ancient monuments of Egypt and India, and before which the Hindoos prostrate themselves to this day.

SARRACENIACEÆ. — The plants of this order have hollow pitcher-shaped leaves, in which insects are entrapped. They chiefly occur in the North American swamps.

PAPAVERACEÆ.—This order consists of very handsome herbaceous plants, annual and perennial, most of which are natives of the temperate parts of Europe and Asia. The leaves are alternate, sometimes deeply cut, and without stipules. The flowers are solitary, elevated on long peduncles, showy, and usually white, yellow, or red; and the bud in all, except the large scarlet Eastern poppies, is shrouded in only two sepals, which fall off as soon as the flower expands. The Oriental species have three sepals, and one of them (*Papaver bracteatum*) has two large bracts which remain after the flower has expanded, and form a kind of calyx, though the real calyx has dropped off. There are generally four petals, or a multiple of four, which are crumpled in the bud, and soon fall off. The stamens are very numerous, inserted in four or more bundles beneath the pistil (*a*). The ovary is solitary, forming a capsule, which consists of several carpels grown together; stigmas generally stellate on the flat apex of the ovary. Notwithstanding the fleshy ovary, the fruit is a dry capsule, with only one cell, the divisions between the carpels having disappeared. The seeds are numerous, have a minute straight embryo, imbedded in albumen, and become loose in the capsule when they are ripe. Before the seeds are ripe, the walls of the capsules become as hard as a shell; and the stigmas, which are grown together, and become equally hard, form a star-shaped lid for the capsule (*b*). Under this there

P. somniferum.

is a set of valves that open for the discharge of the seed.

The British genera are—*Papaver*, the poppy, of which there are many species; *Meconopsis*, the Welsh poppy; *Glaucium*, horned poppy; *Chelidonium*, greater celandine or swallowwort. There are many more, however, grown in our gardens as ornamental plants, such as *Sanguinaria*, or blood root; *Argemone*, the prickly poppy; *Eschscholtzia; Hunnemania; Rœmeria; Hypecoum; Platystemon;* and *Platystigma*. In the horned poppy, which is common on the south-east coast of England, and of occasional occurrence in Scotland, the seed-vessel is formed of only two carpels grown together, which look like a pod; and when ripe, from their length and stiffness, bear a considerable resemblance to a horn; hence the name. The greater celandine, as well as the prickly poppy, has a yellow juice—the juice of the others is white. In the Eschscholtzias the sepals do not separate; but becoming detached at the base, they retain the shape of a hood or extinguisher, till pushed off by the expansion of the corolla. The capsules of the Eschscholtzias are elongated, and are easily known by the large fleshy projection at their base. The plants of the order are easily detected by their general resemblance to each other, especially in their flowers, with the exception, perhaps, of the celandine, the flowers of which are small.

All the Poppyworts abound in a thick glutinous juice, which poisons by stupifying. All parts of the plant furnish more or less this milky sap, but the main supply is derived from the unripe seed-vessels. When in a green state, those of the large white poppy (*P. somniferum*) are slightly wounded with a knife, which causes the juice to exude freely; and on exposure to the air, it concretes or becomes inspissated. In this state it forms crude or lump opium, which, dissolved in spirit of wine, and filtered, produces the laudanum of the shops. Chemically, opium consists of an insoluble gum, a small quantity of resin, and caoutchouc. Its effects on the animal system depend upon two alkaline principles which it contains—namely, morphia and narcotine; the former producing a sedative, and the latter a stimulating effect. It is curious that the seeds possess none of the stupifying properties of the plant, but are mucilaginous and oily, and may be eaten with impunity. The seeds of one species, however (*Argemoné Mexicana*), are said to be narcotic, especially when smoked; but it is probable that in this case the opiate resides in the coating of the seed rather than in the albumen.

Fumariaceæ.—These plants indicate relationship with the preceding order in their two deciduous sepals, and with the following in their cruciate petals; but their habit is quite peculiar, the leaves much cut, often glaucous, and the juice watery. The Fumeworts, so common in hedges and cultivated places, are familiar examples, and their curious flowers deserve attention. When large, they are showy, as in *Diclytra spectabilis* (Chinaman's Breeches), a plant which, although only of recent introduction from China, is already one of the pets of cultivators, occupying equally the cottage-garden and the palace conservatory.

Cruciferæ.—This is one of the most extensive and important of the natural orders. Most of the genera are herbaceous annuals and perennials. The leaves are alternate, and the flowers are produced in corymbs or racemes, being usually regular, with a calyx of four sepals, and a corolla of four petals, disposed in the form of a Maltese cross: hence the name *Cruciferæ*, or cross-bearing. There are six stamens, two much shorter than the others, as shewn under the Linnæan class *Tetradynamia*. The pods open naturally when ripe, the valves curling outwards, as in the common cabbage or turnip, for example. The seeds have no albumen, and the cotyledons are curiously folded down on the radicle. There can be no difficulty in recognising a cruciferous plant when it is in flower, by the cross-form of its corolla, as in the preceding figure, and its six stamens, two of which are shorter than the others.

Crucifer.

Among the more common genera may be mentioned *Brassica*, including the cabbage; *Cheiranthus*, the wall-flower; *Mathiola*, the stocks; *Iberis*, the candy-tuft; *Isatis tinctoria*, the woad; *Cochlearia*, the horse-radish; *Sinapis*, the mustard; and many other well-known plants. Most of them are natives of Europe; but plants of the order, which contains about 170 genera, are found in every part of the world.

The properties of the Crucifers are antiscorbutic and stimulant, combined with an acrid flavour; and the seeds of many abound in a fixed oil: properties of which the common cress, mustard, and rape may be taken as examples. Most of them form articles of human food, and are valuable not only for their antiscorbutic properties, but from the fact that they contain a large amount of nitrogen. All the cultivated varieties of turnip appear to have been derived from *Brassica Rapa*, which occurs in a wild state in Britain. *Isatis indigotica* yields a kind of indigo.

Capparidaceæ.—This order—represented by *Capparis spinosa* of Southern Europe, whose flower-buds are the capers of commerce—is nearly allied to the preceding, but well distinguished by the usually indefinite (numerous) stamens, which are never tetradynamous.

Resedaceæ.—The chief genus is Reseda, to which our sweet mignonette belongs. Flacourtiaceæ is likewise a comparatively small order, one of its plants, Bixa, yielding arnotto, a red dye, which is also used in the manufacture of chocolate. Droseraceæ is chiefly remarkable on account of the glandular hairs on the leaves of our British species which are called Sundews. Venus's flytrap has more irritant leaves. (See Vegetable Physiology, p. 77.)

Malvaceæ.—This is a very marked and natural order, all the plants belonging to it bearing a striking resemblance to each other, and remarkable for their large showy flowers. The petals and sepals are each five in number, but the calyx has three bracts on the outside, which are frequently so near to it as to have the appearance of a second calyx below the true one. Estivation twisted. The most remarkable part of the flower is the central column, and this is so decided, that a botanist is always able to recognise one of the Malvaceæ at first sight. This column is formed by the filaments of the stamens growing together, so as to leave only a small portion just below the anthers free, as is seen in the flower of the marsh-mallow—the lower portion forming a tube round the pistil. The anthers themselves are also peculiar: they are one-celled, kidney-shaped, and burst transversely, opening inwardly. This peculiar construction of the stamens may be observed distinctly in the Lavateras, the hollyhocks, and, in short, in all the genera belonging to the order. The styles also grow together, as may be seen when the stamens are removed; and the carpels, which are of the same number with the styles, form what children call 'mallow cheeses.' The carpels are one or many seeded, sometimes closely united, sometimes separated or separable; fruit capsular or baccate. Most of the species are herbaceous plants; several, trees or shrubs. Leaves alternate, more or less divided and stipulate, often covered with stellate hairs.

Marsh-mallow.

All the plants possess showy flowers, abound in

mucilage, and are destitute of unwholesome qualities. It will be seen that there is a considerable resemblance between the flax and the mallow tribes. Both possess mucilaginous qualities; in both the parts of the flower are in fives; and in both the filaments of the stamens are partially united: though in the flax the union is only at the base, whereas in the mallows it is carried up so as to form the central column, which is so marked a feature of the order. The herbaceous species of the Malvaceæ have woody fibre in their stems, but not in such abundance as in the common flax. The one-celled anther of the mallows, and the central column, are, however, the striking marks of distinction. Plants belonging to the order are found in almost every part of the world, but the cotton-plant (*Gossypium*) will only thrive in hot climates.

The economical uses of the order are highly important. Cotton, on which so much of British commerce depends, is obtained from several species of *Gossypium*, and is the downy hairs which are attached to and envelop the seeds. These hairs, originally of a cylindrical form, at maturity become collapsed into flat bands, and are much twisted. Much confusion exists in botanical works relative to the species of Gossypium, the varying character of the plants having, it is feared, given rise to unnecessary names. The recent researches of Royle seem to indicate that all the forms known in commerce should be reduced to four species of plants—namely, 1. *Gossypium herbaceum*, which is the common cotton-plant in India, and a variety of which, with buff-coloured hairs, supplies the Nankin cotton. 2. *G. arboreum*, the tree-cotton of India, with red flowers and a fine silky cotton. 3. *G. Barbadense*, Barbadoes cotton, called in India Bourbon cotton, which supplies the highly esteemed Sea Island cotton, as well as the Georgia and New Orleans cottons. 4. *G. Peruvianum*, Cavanilles (or *G. acuminatum*), which supplies the Pernambuco or Brazil cotton. The great difference in the value of different kinds of cotton depends chiefly upon the length of staple, precise measurements of which have recently been published by the United States government. There are also great differences, however, in the cleaning of the cotton brought into market, neglect of which has greatly depreciated the value of Indian cotton.

Cotton is not the only textile substance supplied by this family. 'Sunn hemp,' and numerous other fibres, are obtained in tropical countries from the stems of plants of this order, and even the hollyhock of our gardens has recently been introduced under a patent process for the manufacture of cordage and paper. The Malvaceæ thrive chiefly in warm latitudes, but are not uncommon in cold countries, and one beautiful species of *Sida* rises to an elevation of from 13,000 to 15,000 feet on Pichincha.

Many of the Malvaceæ are also medicinal and dietetic. The *pâte de Guimauve*, which is made from a species of marsh-mallow, is much used on the continent in all disorders of the lungs; from the *Althæa officinalis* is prepared, in France, the vegetable tracing-paper known by the name of *papier végetale;* and a blue matter, not inferior to indigo, is said to be obtained from the leaves of the hollyhock (*A. rosea*). The native ladies in India blacken their eyebrows with the flowers of *Hibiscus Rosa Sinensis*, and Europeans apply it to the less honourable purpose of blacking their shoes.

STERCULIACEÆ is an order chiefly remarkable from containing the celebrated baobab, one of the largest trees in the world, its trunk often attaining a circumference of ninety feet. BYTTNERIACEÆ contains the *Theobroma Cacao*, or food of the gods, the seeds of which are the 'cocoa nibs' of commerce, and are employed in the manufacture of cocoa and chocolate; the latter containing in addition sugar, vanilla, cinnamon, and arnotto. This cocoa has, therefore, no connection with the coco-nut, with which popular opinion, misled by similarity of name—and a constant misspelling of the word *coco*—so constantly associates it. TILIACEÆ, represented by the lime-trees in Britain, contains several useful plants, the most important of which is *Corchorus capsularis*, which furnishes the fibre called jute, of which rice-bags are made in warm countries, and carpets in cold ones.

TERNSTRÖMIACEÆ.—This is one of the most interesting natural orders, as, besides other fine plants, it contains the camellias and tea-trees. All the members are trees or shrubs, with very handsome flowers. The leaves are alternate, and without stipules; they are frequently leathery, and are sometimes marked with pellucid dots. The flowers have generally five sepals and five petals; sometimes there are two additional sepals a little below the others. The stamens are numerous, and either grow together into a central column, or are in five distinct bundles. There are but few seeds, which are large, and entirely filled with an embryo having thick cotyledons like the bean, and no albumen.

Only a very few genera belonging to this order have been introduced into this country; but there are a number of equally beautiful species found in the East Indies and South America. Those best known in Britain are the genera *Gordonia*, *Stuartia*, *Camellia*, and the *Tea-tree*. The common camellia—*C. Japonica*—is too well known to need any description, and its beautiful flowers and thick glossy leaves must be familiar to every one. The double varieties are numerous, but the 'old double white,' as it is called, is still the favourite kind for ball-room decoration. The tea-tree is very nearly allied to the camellia, but its flowers and leaves are smaller. The teas of commerce are obtained from two different plants, named respectively *Thea Bohea* and *Thea viridis*, on the supposition that the former produced our ordinary black teas, while the latter afforded *green* tea. It would appear, however, from Mr Fortune's recent researches, that both kinds of tea are manufactured from either plant, the difference mainly depending on the time of gathering and the mode of preparation. The young leaves, quickly dried and subjected to a particular kind of manipulation, form green tea; while the older ones, dried more slowly, and undergoing fermentation, constitute black tea; but in some cases the green colour is imparted by means of a mixture of turmeric, prussian-blue, and gypsum. Teas are sometimes perfumed and flavoured by the addition of the flowers of the fragrant olive and other plants.

Long confined to China, this branch of Oriental agriculture has at length been successfully introduced to the Himalayan possessions of the East India Company. The Assam Tea is furnished by a larger plant than either of the preceding, which is said to be a distinct species.

AURANTIACEÆ.—The golden fruit of the orange and lemon, so characteristic of this order, is so beautiful,

Lemon.

that it is supposed to have been typified by the celebrated apples of the Hesperides. The order consists

of elegant and fragrant trees or shrubs. The leaves, though apparently simple, are called compound by botanists, because they are articulated with the petiole, which in the orange and some other species is winged. The calyx is tubular, with five short teeth. The petals of the corolla are five in number, thick and fleshy, and when held up to the light, they appear full of pellucid dots, which are receptacles of secretion filled with fragrant oil. There are generally twenty stamens, which are divided into five bundles, the filaments in each bundle adhering together. The fruit—hesperidium, as it is called by botanists—is divided into numerous cells by dissepiments, and there is a central placenta, to which the ovules are attached in the ovary; but as the fruit swells, the seeds become detached, and the cells fill gradually with cellular tissue, till at last they become replete with an acid and bitter pulp, in which the seeds are immersed. The seeds are exalbuminous, and sometimes contain more than one embryo.

The most familiar genus is Citrus, the species of which are chiefly natives of the tropics—most of them being found in a wild state exclusively in the East Indies. The orange, however, appears to have an extraordinary facility of adapting itself to any country the climate of which is dry and sunny; and thus have arisen the orange groves of St Michael and of Florida, besides those of Malta, and various parts of Europe and North Africa. All the kinds of orange, lemon, shaddock, citron, &c., belong to the genus *Citrus*. *C. Aurantium* is the sweet orange, so generally cultivated. The principal kinds are the common orange, the Chinese or Mandarin, the Maltese, and the St Michael. *C. medica* is the citron; *C. Limonum*, the lemon; *C. Limetta*, the sweet lime; and *var. Bergamia*, the bergamot; *C. Paradisi*, the forbidden fruit; and *C. decumana*, the shaddock. The Wampee, the fruit of *Cookia punctata*, is much admired in China and the Indian Archipelago, but does not appear to have been introduced into Europe.

All the Aurantiaceæ abound in a fragrant oily matter, which is contained in the receptacles of secretion in the rind of the fruit, and in the leaves of the tree. The pulp of the fruit is more or less acid, and is used either in its natural state, or medicinally in various forms. About 35,000 tons of oranges are said to be annually imported into Great Britain. The productiveness of the common orange is enormous: a single tree at St Michael has been known to produce 20,000 oranges fit for packing, exclusively of the damaged fruit and the waste, which may be calculated at one-fifth more.

GUTTIFERÆ.—Woody plants, with opposite, entire leaves, numerous stamens, often united, seeds exalbuminous, often immersed in pulp. These plants occur in humid localities in the tropics. The East Indian resin, called Tacamahac, is furnished by *Calophyllum Calaba*, while the *Mammea Americana* affords the mammee apple or wild apricot of South America. One of the finest of known fruits—the mangosteen—also belongs to this order. Gamboge is obtained from different species of Garcinia and Cambogia—the best kind, it is said, being that moulded in the hollow stems of bamboo.

ACERACEÆ.—This order consists of about sixty species, all of which are trees natives of temperate climates. The leaves are opposite, and without stipules; they are generally large and handsome, with five or seven lobes, though the *Negundo*, or box-elder, has the leaves pinnate. The flowers are small, but pretty, being in long drooping racemes or corymbs. The male and female flowers are distinct. The stamens, which are eight in number, are the only conspicuous part of the flower, as the petals are frequently wanting. The bracts are large and leathery, and generally roll back when the flowers expand. Most people have seen the fruit, or *keys*, as they are called, of the sycamore and maples, the botanical term for which is *samara*. This kind of fruit consists of two cells joined together on one side, each having a long membrane-like wing. There is usually only one seed in each cell; the embryo has two, and sometimes three, large thin cotyledons, which are curiously folded up, and fill the whole seed. This is rather a remarkable feature of structure, as where there is no albumen, the cotyledons are for the most part fleshy.

The genus *Acer* comprehends all the maples and the sycamore. *Negundo* is easily distinguished from the maples by its compound leaves, which resemble those of the ash. The male and female flowers of this genus are developed on different trees, being very inconspicuous. The common maple (*A. campestre*) and the sycamore, or 'plane-tree,' as it is called in Scotland (*A. pseudo-platanus*), are the only members of the order natives of Britain, though a number of other species have been introduced by culture. The Negundo belongs to America.

The sap of the maples is remarkably sweet, and sugar is frequently made in America from that of *A. saccharinum*. Indeed, the sugar-maple may be said to be a rival of the sugar-cane, the United States alone producing not less than 10,000,000 pounds per annum. The timber of the maples and sycamore is remarkably light and close-grained, and therefore much used in veneering and inlaying. The bark is astringent, and yields the dyer reddish-brown and yellow colours.

SAPINDACEÆ.—The Soapworts are woody, rarely herbaceous plants, with usually compound leaves and unsymmetrical flowers, most of them being found in the hot parts of India and America, and little known in Europe, except from the writings of travellers. This remark will not apply, however, to the *Hippocastaneæ*, or horse-chestnuts (distinguished by their opposite leaves, and by the ovary having two ovules—one erect, the other suspended—in each cell), which are natives of Northern India, Persia, and the American States. This section consists of only two genera—namely, *Æsculus*, the horse-chestnut; and *Pavia*, the scarlet-flowering chestnut. The species are all trees and shrubs, natives of temperate climates. The leaves are palmate—that

Æsculus Hippocastanum.

is, divided into five or seven parts; and are without stipules. The flowers are produced in large panicles or racemes; and are very handsome. There are five petals, two of which are smaller than the others, and all have small claws. In the scarlet horse-chestnut, and some other kinds, there are only four petals; and in the *Pavia*, two of the petals are so much smaller than the others as to look like leafy stamens. There are seven stamens, three of which are much shorter than the others The fruit of the horse-chestnut consists

of a leathery husk, which opens when it is ripe into three valves. The husk of Pavia is smooth. The scar of the hilum is very strongly marked on the testa of the nuts of both genera; and in Pavia it is so conspicuous as to give rise to the American name of the genus, which is called *Buck's-eye*, from the resemblance of the hilum to the pupil of an eye. When the seed is put into the ground, the cotyledons only open sufficiently to allow the escape of the plumule and the radicle. The plumule is very large, and has two leaves in the seed; and the radicle is close to the hilum, where of course is also the foramen. There is no albumen, the nourishment for the young plant being laid up in the thick fleshy cotyledons.

The horse-chestnuts, which belong originally to the north of India, have been so long cultivated in Europe, as now to spring up like natives of the soil. The Pavias are all natives of North America. Both of the genera are amongst the finest of our flowering-trees, and on this account are common in park-scenery. The seeds of the order abound in starchy and in saponaceous matter. The bark of the common *Æsculus Hippocastanum* is bitter, astringent, and has been recommended as a valuable febrifuge in intermittent and other fevers.

VITACEÆ.—This order comprises about 260 species, natives of temperate climates. Their prevailing habit is a long dangling growth of stem, thyrsus of colourless flowers, with tendrils opposite the leaves, and bunches of berried fruit. The stem and branches are furnished with tumid articulated nodes; the leaves are lobed or compound, generally alternate with stipules. The flowers are small, often the male and female distinct; calyx, very small; sepals and petals, four or five, the latter sometimes cohering at the tips, and falling off before the bursting of the anthers; stamens, equal in number to the petals, and opposite to them; ovary, two-celled; fruit, a berry, with the seeds immersed in pulp; seeds with a bony testa; albumen, hard; embryo, small. The curious formation of the flower and berry is well illustrated by the dissection of the common vine, as shewn in page 88.

The genera are—*Ampelopsis*, the vine-leafed ivy; *Vitis*, the grape-vine; *Leea*, *Cissus*, *Pterisanthes*, and *Rhaganus*. With the exception of the vine, the other genera are of little interest, being employed only as ornamental creepers. *Leea* is considered by some to be nearly allied to the Meliaceæ, forming as it were a connecting-link between the two orders.

The properties of the grape, either in its fresh state or dried to form raisins, or expressed and fermented to form wine, &c., are too well known to require description. The average import of raisins to Britain amounts to 12,000 tons, the finest being the Muscatel. The dried currants of commerce—a corruption of Corinths—are the produce of the small seedless Corinthian grape, which is cultivated in many islands of the Mediterranean. Currants are annually imported to the extent of 21,000 tons. *Vitis vulpina* is a kind of wild vine which produces what are called fox-grapes in North America; it forms an ornamental creeper, being hardy in Britain; and has recently attracted notice as likely to form a good stock on which to graft our grape-vines. The ravages of the grape-blight, which has of late years spread devastation over the wine-countries, might be thus in great measure prevented. (See THE FRUIT GARDEN.) The Kangaroo Vine of Australia, which is well suited as an indoor window-creeper, is a species of *Cissus*. The berries of the Virginian creeper (*A. hederacea*) are small and unpalatable, but might be eaten with perfect safety. According to Von Martius, the leaves and fruit of *C. tinctoria* abound in green colouring-matter, which soon becomes blue, and is highly esteemed by the natives of Brazil as a dye for cotton fabrics. Acid leaves, and a fruit like that of the common grape, are the usual characters of the order.

GERANIACEÆ.—The *Geraniaceæ* comprise only five genera, but about 500 species. They are herbs or shrubs, with stems which are tumid and articulated at the joints. The leaves are generally lobed, and furnished with small stipules. Calyx persistent in five-ribbed sepals. Corolla generally five-petalled, with strongly marked veins. Stamens twice as many as the petals; filaments united at the base. Fruit consists of five elastic one-seeded carpels, adhering to an elongated central axis, from which they part with an elastic jerk when ripe. Seed without albumen; cotyledons rolled up or folded.

The chief genera are *Geranium*, *Pelargonium*, and *Erodium*, respectively crane's-bill, stork's-bill, and heron's-bill, from the fancied resemblance of the ripe seed-vessel to these objects. Many of the species, which are very widely distributed, are natives of Europe; but the majority of our green-house favourites are from the Cape of Good Hope. The herb Robert (*G. Robertianum*) and the meadow crane's-bill (*G. pratense*) are British plants, as are also *E. cicutarium* and *moschatum*. All the pelargoniums have their flowers in heads, or umbels, and the calyx remains till the seeds are ripe. Their leaves vary very much, some being round—as the horseshoe geranium—and marked with a dark line; and others are deeply lobed, as some of the scented varieties.

The Geraniaceæ are all innocuous plants, being generally slightly acid, and sometimes astringent. They are all more or less fragrant, secreting oils and resins; and in some these secretions are so abundant (*Monsonia spinosa*), that the stems burn like torches, and emit an agreeable odour during combustion. In America, the roots of *G. maculatum* are used as a remedy for diarrhœa; the British Erodiums are sometimes employed as aromatic bitters; from *P. odoratissimum* a fragrant oil has been distilled, resembling the attar of roses; the underground tubercles of *P. hirsutum* are esculent, and prized by the Arabs as food; and Mr Backhouse, in his recent travels, mentions that the tubers of *G. parviflorum* are eaten by the natives of Tasmania, where it is called the Native Carrot. Notwithstanding these uses, the members of the order are chiefly esteemed for the beauty of their flowers, and have long continued among the most admired favourites of the conservatory. The geraniums or pelargoniums which we see at horticultural exhibitions, are chiefly hybrids and improved varieties of the Cape species of *Pelargonium*.

LINACEÆ.—A very small order. The flowers are in five parts, like those of the cloveworts; but the sepals of the calyx are always distinct, and, instead of being arranged in a regular whorl, two are placed a little lower than the others, as in the *Cistaceæ*. There are five styles and stigmas; but the seed-vessel splits into ten valves, each carpel containing two seeds, separated by an obscure partition, which gives the carpels the appearance of being only one-seeded. The seeds are flat and shining, with a large embryo.

The only genera are Linum and Radiola; the former comprehending many species. *L. catharticum* is the purging-flax of rural practice. But of all plants of the order, the common flax (*L. usitatissimum*) is the most important and best known. Flax will grow in almost any part of the world; and though an annual, its stem contains so much woody fibre, that it is exceedingly tough and durable, yielding by maceration the flax of commerce. This external coating of tough fibre, and the peculiar construction of the flower, are amongst the most obvious distinctions of the tribe, though only one or two yield fibre sufficiently strong for economical purposes. The seeds contain a great quantity of oil (*linseed-oil*), which is obtained from them by pressure, and the refuse forms *oil-cake*, employed by farmers in feeding cattle. The seeds also abound in mucilaginous matter, and are thus made use of medicinally, for coughs, &c.; or, when ground into meal, for poultices. Though lint was at one time pretty extensively grown in Britain,

our manufacturers now derive the greater part of their supplies from the countries adjoining the Baltic, from which, in one year, not less than 70,000 tons of flax, and about 2,000,000 bushels of linseed, have been imported. The Valley of the Nile, anciently celebrated for its fine linen, now yields but an inconsiderable quantity, in consequence of the present barbarous condition of the inhabitants. It is there cultivated during the cold season. Of late years, the fibres of flax, by being steeped in a solution of carbonate of soda, and afterwards dipped in a weak acid solution, are so broken up as to form a substance like cotton, which is manufactured in the same way as that fabric.

These and the other orders tabulated in page 89 comprise all the plants belonging to the sub-class THALAMIFLORÆ. They include several interesting members, some of which are of the greatest importance to man. Many of the genera contain only herbaceous plants; and the timber-trees that are among them have all comparatively light wood, though it is generally fine grained, and in some extremely beautiful. Flax and cotton, both belonging to this division, are also of the greatest economical importance. The contrast between the durability of these two kinds of thread is very striking, and of peculiar interest to the student of vegetable physiology. Linen thread, being the *woody fibre* of the flax-plant, is much stronger than cotton thread, which is composed entirely of *cellular tissue*. Though the seeds of many plants are abundantly enveloped in down, that of the cotton is the only one capable of being spun into thread. The Bombax, or silk-cotton-tree, forms no exception to this statement, because though the silky hairs that surround the seeds are used to stuff cushions and beds, and though a sort of felt has been made of them, yet they cannot be spun into threads of sufficient tenacity to endure weaving. Ropes, and other fabrics, are manufactured from the barks of many of the trees and plants included in this division. Cocoa and chocolate, tea, wine, oranges, lemons, maple-sugar, opium, several fruits, drugs, dyes, and oils, are the produce of plants belonging to this division; and to these may be added cabbages, mustard, horse-radish, turnip, and other esculents.

§ CALYCIFLORÆ.

The plants comprised in this sub-class are dichlamydeous—that is, having both calyx and corolla—as in the preceding; the petals are usually separate, but sometimes united; the stamens perigynous, arising from the calyx, and thus surrounding the ovary; or epigynous, arising, apparently, from the upper part of the ovary, which is in this case inferior as regards the parts of the flower. It has been separated into two divisions: the one named *Polypetalæ*, from the petals being several and separated; the other *Monopetalæ*, from their being so united as to appear single; for example, a wild rose has five distinct petals, separate to the base, whereas a bell-flower (Campanula) has all its petals united into one piece. In no case do the stamens arise directly from the thalamus, which is the characteristic of the preceding sub-class. Here the parts of the flower are more or less united to each other. The following are the orders belonging to Calycifloræ:—

POLYPETALÆ.

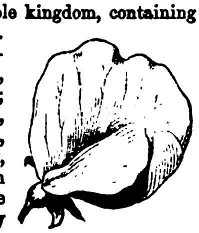
Stackhousiaceæ — Stackhousiads.
*Celastraceæ—Spindle-trees.
*Staphyleaceæ—Bladder-nuts.
*Rhamnaceæ—Buckthorns.
Anacardiaceæ—Cashews.
Amyridaceæ—Myrrh order.
Connaraceæ—Connarads.
*Leguminosæ or Fabaceæ—Leguminous Plants.
Moringaceæ—Moringas.
*Rosaceæ—Rose order.
Calycanthaceæ—Calycanths.
*Lythraceæ—Loosestrifes.
Rhizophoraceæ—Mangroves.
Vochysiaceæ—Vochysia order.
Combretaceæ—Myrobalans.
Melastomaceæ—Melastomads.
Alangiaceæ—Alangiads.
Philadelphaceæ—Syringas.
Myrtaceæ—Myrtles.
Chamælauciaceæ — Fringe-myrtles.
Lecythidaceæ—Monkey-pots.
Barringtoniaceæ — Barringtonias.
*Onagraceæ—Evening Primroses.
*Halorageaceæ—Mare's-tails.
Loasaceæ—Chili-nettles.
*Cucurbitaceæ—Cucurbits.
Papayaceæ—Papaw-worts.
Belvisiaceæ—Belvisiads.
Passifloraceæ — Passion-flowers.
Turneraceæ—Turnera order.
*Portulacaceæ—Purslanes.
Illecebraceæ—Knotworts.
*Crassulaceæ—Stonecrops.
Mesembryanthemaceæ—Fig-marigolds.
Tetragoniaceæ—Tetragonias.
Cactaceæ—Indian figs.
*Grossulariaceæ—Gooseberry order.
Escalloniaceæ—Escalloniads.
*Saxifragaceæ—Saxifrages.
Hydrangeaceæ—Hydrangeads.
Cunoniaceæ—Cunoniads.
Bruniaceæ—Bruniads.
Hamamelidaceæ—Witch-hazels.
*Umbelliferæ or Apiaceæ—Umbel-bearers.
*Araliaceæ—Ivyworts.
*Cornaceæ—Cornels.

MONOPETALÆ.

*Loranthaceæ—Misletoe order.
*Caprifoliaceæ—Honeysuckles.
*Rubiaceæ — Cinchona and Bedstraw order.
*Valerianaceæ—Valerians.
*Dipsaceæ—Teazelworts.
Calyceraceæ—Calycera order.
*Compositæ or Asteraceæ—Composites.
Brunoniaceæ—Brunoniads.
Goodeniaceæ—Goodeniads.
Stylidiaceæ—Styleworts.
*Campanulaceæ—Bell-flowers.
*Lobeliaceæ—Lobeliads.
Styracaceæ—Storax order.
Columelliaceæ — Columellia order.
*Vacciniaceæ—Cranberries.

ANACARDIACEÆ.—This order is chiefly found in tropical America, Africa, and India, in the form of woody plants, with alternate exstipulate leaves, and small, sometimes unsexual flowers. Sepals, 3–5 united; petals, 3–5 imbricate; stamens, variable in number; ovule, solitary, with a long curved cord attached to a basal placenta; the fruit, a nut or drupe, indehiscent. They abound in a resinous or milky acrid, and poisonous juice; but their fruits are often edible, instances of which we find in the cashew-nut (*Anacardium occidentale*), where the kernel is edible, while its covering is acrid. The mango is a highly prized tropical fruit, produced by a plant of this order (*Mangifera indica*), of which there are many varieties in cultivation. The genus *Spondias* affords the eatable fruit called hog-plums, while pistachio-nuts are derived from *Pistacia vera*. On the other hand, several poisonous species have been brought into the service of man: as *Rhus Toxicodendron*, the Poison Oak, which has been used as a remedy in paralysis. The varnish of Martaban is traced to *Melanorrhœa usitatissima;* while Japan lacker is supplied by *Stagmaria verniciflua*, a native of the Indian Archipelago, and mastich by several species of *Pistacia*. The pe-la wax of China, which is now being introduced to European commerce, is furnished by an insect which feeds upon *Rhus succedaneum*.

LEGUMINOSÆ.—This is one of the most extensive and best defined orders in the vegetable kingdom, containing upwards of 6500 known species. Many of its plants bear butterfly-shaped (papilionaceous) flowers, and all have pod-like seed-vessels; among which may be mentioned, as familiar examples, the pea, vetch, bean, lupine, restharrow, broom, furze, and laburnum. In an order so extensive, it may be expected that there will be many minor differences requiring subdivision into tribes; but without adverting to these in the meantime, the following may be stated as the general characteristics of the *Leguminosæ:* —Herbs, shrubs, or trees; leaves, alternate, generally compound, their petioles tumid at the base, where there are usually two stipules, and also two to each leaflet in the pinnate leaves; the pedicels are generally articulated, and the flowers are furnished with small bracts; calyx, five-parted, the segments being sometimes unequal and variously combined; petals, never more than five, but often less, and sometimes wanting, inserted into the base of the calyx, and variously arranged, papilionaceous in all European genera, the odd petal being always



Papilionaceous.

superior; stamens, definite or indefinite, inserted with the petals, in exceptional cases apparently hypogynous, thus shewing a transition from the preceding sub-class, distinct, or in one, two, or three bundles; ovary, superior, for the most part one-celled; ovules, one or many; style and stigma, simple; fruit, a true legume, a modified form of legume or loment, or sometimes, when containing only one seed, drupe-like; embryo, straight, with or without albumen; the radicle, in some instances, bent along the edge of the cotyledons.

This family, says a recent writer, is amongst the most important to man, whether as affording objects of beauty, of utility, or of nutriment. The bean, the pea, the vetch, and the clover tribe belong to it; as do the logwood, the laburnum, indigo, the tamarind, liquorice, senna, and the acacias. Its general properties are considered by some to be wholesome, but there are several exceptions. Thus, the seeds of laburnum, and the juice of *Coronilla varia*, are poisonous. Senna, obtained from various species of cassia, is purgative, and several others of the order possess a similar property. The pericarp of some contains much tannin; dyes are obtained from others; and many yield gums and balsams. It would consume pages to enumerate all the uses to which this, one of the most extensive orders in the vegetable kingdom, has been applied. We shall, therefore, briefly indicate the principal sections of the order, and the more important plants contained in each. § I. *Papilionaceæ*, petals papilionaceous, imbricate, upper one exterior. This, which may be called the Pulse section, is the only one containing British species, but these are numerous, and contribute much to the beauty of our Flora. The vetches and lathyrus of our hedgerows, the restharrow of sandy banks, the trefoils and clovers of our fields, the lotus of our meadows, and the meliloti of ballast hills, are all gay flowers which we gather in our rural walks. Turning to plants of utility, we find here the bean and the pea, so well known as farm and garden crops, the clovers, vetches, saintfoin, lucerne, and other forage plants which form the mainstay of modern farming. The lentil (*Ervum lens*), although a crop of the most ancient cultivation, has only recently been introduced to the notice of British farmers, and may possibly be of some service on light soils. Kidney-beans and scarlet-runners also belong to the list of garden Papilionaceæ, the latter affording a characteristic illustration of the miscellaneous properties of this order, its roots being poisonous, while its seeds form an article of food. Other plants of the section are decidedly poisonous, such as *Coronilla varia*, and the seeds and bark of laburnum, which, being a common ornamental tree, and one which seeds freely, is apt to give rise to accidents, especially in the case of children. But perhaps the most remarkable of all poisonous species is the ordeal bean of Calabar, which was recently described to the Royal Society of Edinburgh by Dr Christison; but its genus is not precisely determined. It appears to be commonly used in Calabar, in trials by ordeal, the suspected party being set free if (by vomiting) the bean does not prove fatal. In like manner, the bark of another species is used by the Caffres as a test in judicial trials. Of miscellaneous plants used in the arts, we find *Astragalus gummifer* and other species, from which gum tragacanth is obtained; *Baptisia tinctoria*, a dye-plant and the wild indigo of America; *Crotalaria juncea*, whose fibrous bark yields Bengal hemp; *Dalbergia Sissoo*, which in India yields the valuable timber well known by its native name of Sissoo; *Dipterix odorata*, whose fragrant seeds are the Tonka-beans of commerce; *Glycyrrhiza glabra*, whose root forms liquorice; various species of *Indigofera*, from which the true indigo is obtained; *Pterocarpus santalinus*, the source of red sandal-wood; *P. draco*, which yields gum dragon; and *Triptolomea*, from species of which the rose-wood of commerce appears to be derived. Kino is supplied by various species of *Pterocarpus*, and by *Butea frondosa*, one of the most gorgeous plants of India, whose masses of bright orange-red flowers, with jet-black velvety calyces, are described by Dr Hooker as resembling sheets of flame. § II. *Cæsalpinieæ*, petals imbricated, upper one interior. The plants of this section are chiefly important from yielding valuable timbers and dyes, while some are much used as purgative medicines. Of the latter, the various kinds of senna, consisting of the leaves of species of *Cassia*, are most important. The fruit of the tamarind likewise contains a laxative pulp, as also *Cassia Fistula*. Of dyes we have the sappan of India (*Cæsalpinia sappan*), the barwood or camwood (*Baphia nitida*), and the well-known logwood (*Hæmatoxylon campechianum*). Of timber-trees, the Brazil-wood of commerce (*Cæsalpinia Brasiliensis*) is not the least important. The West Indian locust-tree (*Hymenæa Courbaril*) affords a close-grained tough wood, which is found well adapted for the beams of steam-engines, while the Guiana purple-heart even excels it in toughness; and being found to resist well the shock of artillery discharges, it is sought after for mortar-beds. Lindley speaks of the locust-trees of the West as long celebrated for their gigantic structure, while other species are the colossi of South American forests. Martius represents some as eighty-four feet in circumference at the base of the stem; by counting their concentric rings, he arrived at the conclusion that they were of the age of Homer, and 332 years old in the days of Pythagoras. One estimate reduced their antiquity to 2052 years, but another carried it up to 4104; from all which he argues that the trees cannot but date far beyond the time of our Saviour. § III. *Mimoseæ*, petals valvate in estivation. The principal genera are *Acacia* and *Mimosa;* the latter genus chiefly remarkable on account of the irritability displayed by the leaves of *M. pudica* and *sensitiva*. Many species of *Acacia* yield gum-arabic and gum-senegal. The Australian species, called 'Wattles,' have astringent bark which is used in tanning; in these the leaf-stalk is often flattened into a phyllodium, or false-leaf; in the young plant there may be no compound leaves developed, but these ultimately appear at the tips of the phyllodia.

ROSACEÆ.—Like the preceding, this is one of the most extensive natural orders, comprehending nearly 1000 described species, which are herbs, shrubs, and trees, often of very dissimilar habits and appearance, but all bearing a striking resemblance in their fructification to the single or wild rose of our woods and hedges, which may be taken as the type of the order. Among the trees may be mentioned, as familiar examples, the almond (*Amygdalus*), the pear and apple (*Pyrus*), the sloe and plum (*Prunus*), the peach and nectarine (*Persica*), the cherries and laurels (*Cerasus*); among the shrubs, the rose (*Rosa*), the hawthorn (*Cratægus*), the bramble and raspberry (*Rubus*), and the quince (*Cydonia*); among the herbs, the common yellow *Potentilla* of the roadsides, the *Geum*, the *Tormentilla* of our woods and commons, and the delicious strawberry (*Fragaria*). From the mention of these plants, the reader will be enabled to form some idea of the order, and to perceive that the varied nature of its genera requires a subdivision into several tribes for the purposes of detailed description. All the different sections into which the *Rosaceæ* have been arranged, exhibit the following general characteristics:—Leaves, alternate, generally compound, and always furnished with stipules; calyx, five-lobed, united below, but separate and expanding above; corolla, of five, or sometimes four petals. The ovary is one-celled, and there is seldom more than one seed, scarcely ever more than two in each cell. Carpels numerous, and generally enclosed in the fleshy tube of the calyx.

Rosaceous Flower.

Rosaceæ is usually divided into the following tribes:—1. CHRYSOBALANEÆ, or cocoa-plum family, represented by *C. icaco*, an irregular shrub, eight or ten feet high, found in South America and the West Indies, where its fruit, which is about the size of a plum, of a whitish-yellow, and possessing a sweetish taste, is brought to the markets. There are about nine genera belonging to this tribe, all of which are trees or shrubs, with simple alternate stipulate leaves, and flowers in racemes or panicles. They are natives of the warmer parts of Africa and America, and differ from the almond tribe in having irregular petals and stamens, and in the style arising from the base of the ovary; the stipules are not united to the petiole. 2. AMYGDALEÆ, or almond family, represented by the common almond (*Amygdalus communis*), and embracing the peach, apricot, nectarine, plum, cherry, &c., well known for their delicious fruits, and a few bushes remarkable for their gay appearance during the flowering season. The fruits of this tribe are for the most part edible; and though the leaves and bark possess medicinal properties, yet one of the most subtile poisons—prussic acid—can be extracted both from the fruit and leaves of the almond. 3. SPIRÆEÆ, deciduous shrubs and perennial herbs, represented by *Spiræa salicifolia*, or brideswort. In this section the five-cleft calyx is lined with the dilated receptacle, which forms a sort of cup for the carpels, which are in the form of follicles. The beautiful hardy shrub named *Neillia thyrsiflora* belongs to this tribe, which contains a large number of shrubby ornamental *Spiræas*, as well as herbaceous kinds. 4. DRYADEÆ, embracing those plants which agree with the common *Potentilla* in the construction of their flowers—that is, in having a calyx of ten sepals; its tube short, or nearly flat, not enclosing the fruit; a corolla of five petals; and the stamens, which are numerous, forming a ring round an elevated or flat receptacle, on which are placed numerous carpels. By this test the student will find that the section comprises not only herbs, such as the potentilla, geum, tormentilla, and strawberry, &c., but also erect and trailing shrubs, as the raspberry and bramble. These genera, though alike in their flowers and in many of their habits, are otherwise very dissimilar. In the potentilla, for example, the carpels form the prominent part of the so-called fruit, while in the strawberry the receptacle dilates and becomes edible. Again, in the raspberry the receptacle is a torus surrounded by the carpels, which swell out and soften, forming the edible portion. The leaves and stems of these genera are also very dissimilar, but the habit of increasing by suckers or runners is very prevalent in all. 5. SANGUISORBEÆ, a section of herbaceous perennials, illustrated by *Sanguisorba officinalis*, or the weed burnet of our pastures. This tribe is distinguished by having one or two achenes enclosed within the dry calyx-tube. The flowers often have no petals, but the clefts of the calyx are coloured instead, and the flowers are generally furnished with glossy coloured bracts. 6. ROSEÆ, or roses proper, the type of which is the single wild-rose, or dog-rose of the hedges. The general characters of this section are too well known to require much description. It is distinguished botanically by the numerous achenes enclosed in a fleshy calycine tube which is contracted at the orifice. They have all a corolla of five equal slightly indented petals, capable of being increased indefinitely by cultivation; numerous stamens; a five-cleft calyx. The pitcher-shaped portion of the calyx becomes the hip as the seeds ripen, and forms a false pericarp, enclosing the numerous bony carpels. Many of the plants have pinnate leaves and prickly stems—the prickles differing from thorns in being articulated to the stem—that is, of being separable without tearing the bark. Most of them are fragrant, and the leaves of some, as the sweetbrier, are replete with a fragrant volatile oil, which appears to be secreted by beautiful glands dispersed all over the foliaceous surface of the plant. 7. POMEÆ, an extensive and varied section, the type of which is the common apple (*Pyrus malus*). It comprehends the apple, pear (*Pyrus communis*), the mountain-ash (*P. aucuparia*), the wild service (*P. torminalis*), the quince (*Cydonia*), and the hawthorn (*Cratægus*). In all of these genera, which are trees and shrubs, the flowers are remarkably similar; but the habits of the plants, the leaves, and the fruit, present numerous differences.

The properties of the order have already been so far noticed in the preceding detail, that it may be stated of them generally as follows:—The fruit of some of the *Chrysobalaneæ* is eaten under the name of the cocoa-plum. The *Amygdaleæ*, including the almond, plum, cherry, sloe, &c., are well known; the leaves and kernels contain prussic acid, which, in a concentrated form, is one of the subtilest poisons; but being generally diluted in a natural state with gum, sugar, &c., it is harmless, and serves to give an agreeable flavour to the fruits containing it. Of the *Potentilleæ*, the roots of several are astringent and febrifugal, and the fruits of such as the raspberry and strawberry are delicious and wholesome. The *Roseæ* are chiefly valued for their ornamental flowers, but they also yield valuable extracts—as attar of roses, rose-water, conserve of roses, &c. The fragrant essential oil called attar of roses is distilled chiefly from the common cabbage-rose (*Rosa centifolia*) and its varieties; 20,000 flowers of roses are required to make a rupee weight of the attar, which sells for £10. The common dog-rose of our hedgerows yields an astringent fruit employed in diarrhœa, and is used by gardeners as a stock on which to bud the fine kinds of exotic roses. The *Pomeæ*, under cultivation, supply wholesome and delicious fruits, of which the apple, pear, quince, and service-berry are familiar examples.

MYRTACEÆ.—This important order consists of upwards of 60 genera, and about 1300 species. They are all trees or shrubs, often with angled branches, with simple exstipulate leaves, which are for the most part opposite, full of transparent dots, and with an intra-marginal vein round the edge. The substance of the leaf is coriaceous, and the dots are glands, or cysts, full of a fragrant volatile oil. The inflorescence is both terminal and axillary, variable in its form, but generally aggregate—the flowers being regular and united, of a white, red, or sometimes yellow colour, but never blue. The tube of the calyx adheres to the ovary, and is from four to eight cleft, persistent or deciduous. The petals, which are rarely wanting, are equal in number to, and alternate with, the segments of the calyx; the stamens are inserted with the petals, and are twice as many, or (usually) indefinite, and then arranged in several series;

Pomegranate.

the anthers are oval, two-celled, and burst longitudinally. Fruit, baccate or capsular; style and stigma, simple; many-celled, or one-celled by the obliteration of the

dissepiments of the carpels. Seeds, generally indefinite, seldom few, and without albumen.

The myrtle-blooms are possessed of many useful as well as ornamental properties. Among the edible fruits may be mentioned the delicious guava, yielded by several species of *Psidium;* the rose-apple and jamrosade, produced by *Eugenia* and *Jambosa.* Of spices yielded by the order, which are all more or less aromatic, we have the clove, which is the unexpanded flower-bud of the *Caryophyllus aromaticus;* all-spice, Pimento or Jamaica pepper, the dried berries of *Eugenia pimento;* and also the dried berries of the common myrtle. It is the volatile oil found in the dots of the leaves, the unexpanded petals, and in almost all the parts of the plant, that gives to them their fine aromatic fragrance. The pomegranate (*Punica granatum*) forms a delicious fruit in warm countries; the pericarp or rind is used in the East as an astringent; and the bark of the root is esteemed an efficient anthelmintic.

Some species of the beautiful genus *Metrosideros* yield hard and heavy timber, which the South Sea islanders prize for their clubs and other weapons of war. The gum-trees of Australia deserve special notice as among the most valuable economical plants of our Australian colonies. They are distinguished by a remarkable operculate calyx, and their bark separates in layers, giving rise to the statement that the trees of Australia shed their bark instead of their leaves in winter. Their leaves often stand in a vertical position, and are remarkably hard and coriaceous. These trees grow to an enormous size, and yield very durable timber, where it is capable of being worked. They supply the place of the European oaks as a source of tannin. *E. resinifera* yields, on incision, an astringent matter, called Botany Bay kino; while several others yield saccharine matter. A peculiar red gum is contained in cavities of the wood of *E. robusta.*

LECYTHIDACEÆ.—This order is remarkable from the usually circumscissile dehiscence of its fruits, which form the monkey-pots so common in museums of vegetable products.

CUCURBITACEÆ.—This is a large and interesting family of herbaceous plants, containing 56 known genera, and about 300 species. The roots are annual or perennial, fibrous or tuberous; the stems succulent, climbing by means of lateral tendrils formed of the abortive stipules, and furnished with large alternate, palmated rough leaves. The flowers are usually unisexual.

The Cucurbits are natives of all hot climates, but are most abundant in India; a few exist in the northern parts of Europe and America, and some are found at the Cape of Good Hope.

In an economical point of view, the order is of considerable importance, furnishing the well-known esculents—the cucumber, melon, gourd, pumpkin, and calabash; and the purgatives colocynth and elaterium. The general properties of the gourd family may be regarded as bitter and purgative—these qualities pervading more or less all the species, and rendering their fruit either esculent or purgative. The seeds of all are sweet and oily, and from some a considerable quantity of fine-flavoured oil may be expressed. The roots and leaves are sometimes replete with a bitter drastic juice. The fruit of many of the members grows to an enormous size; the calabash, for example, being sometimes found six feet long and eighteen inches in circumference. *Gherkins* are the fruit of the common cucumber, pickled when in a young state. The fruit of *Lagenaria vulgaris* is in common use for water-bottles in the Greek islands and generally in the East. It has probably given rise to the clay water-bottles in form of a round bulb ending in a long neck, which much resemble it in shape, and to which the bottles in use all over the world may be traced as modifications. Many of the ornaments of ancient Egyptian architecture are traceable in a similar manner to vegetable forms peculiar to the region.

CACTACEÆ.—The Indian figs, or Cacti, constitute one of the most singular and interesting orders in the vegetable kingdom. They are unique in their forms and habits, having perennial succulent, angular, or rounded spiny stems. In general, the stems and branches are jointed; the leaves are either very minute, or altogether wanting, their place being supplied by strong spines. They are all natives of tropical America, but thrive well in all hot, dry, and exposed places. Of the more common genera, we may mention the following:—*Mammillaria*, so called from the pap-like tubercles which cover its sub-cylindrical stem. Each tubercle is crowned with a little tuft of radiating spines; and the flowers, which are sessile, are ranged in a kind of zone round the plant. The melon cactus (*Melocactus communis*), which has a more or less globose stem, with alternate furrows and ridges, the latter being armed with tufts of spines; the stem is crowned by a woolly tuft, from which spring the flowers. The hedgehog-thistle (*Echinocactus*) has also a globose stem, but wants the woolly head, and has its flowers springing from the tufts of spines which arm the ridges. The torch-thistle (*Cereus*) has the stem angular, the projecting angles being armed with spiny tufts, from which the flowers generally spring. The old-man cactus (*Pilocereus senilis*) is so called from its resemblance to an old man's head, being covered with long white hairs. In our hothouses, it is generally of small size; but in its native country it is said to attain the height of twelve or fifteen feet. The Peruvian torch-thistles (*C. peruvianus* and *hexagonus*) are still more gigantic plants, often attaining a height of forty feet, though their stems be not thicker than a man's arm. The rat's tail cereus (*C. flagelliformis*) is well known from its long whip-like stems, which hang down from the sides of the suspended pots in which it is usually grown. The night-flowering cereus (*C. grandiflorus*), so called from its blossoms opening during night, and fading before morning, has an angular, branched, and climbing stem, throwing out roots at every point. The flower is of large size and magnificent, the rays of the calyx being of a bright yellow when open, and the petals of the most delicate white. The genus *Rhipsalis* has slender-jointed stems, which look like samphire; and the opuntias, which are numerous and useful, are distinguished by their round, flat, leaf-like bodies, united together by joints, and for the most part covered with spines.

The fruit of many of the Cactaceæ is esculent, but is rather insipid, having little of that acidulous flavour which characterises the Currantworts, to which the family is allied. It is upon the *Opuntia cocchinellifera*, the Nopal plant, that the cochineal insect, so valuable in the arts, chiefly feeds. It is stated that not less than 800,000 pounds of cochineal are annually brought to Europe, one-fourth of which is consumed in Britain alone, at the cost of £300,000 sterling; so valuable to man is an insect which ignorance would be apt to regard as mean and insignificant. In the south of Europe, the prickly pear (*O. communis*) is reared as a hedge, and also for its fruit, which is edible, and yields a rich carmine pigment; and the Indian fig (*O. tuna*) is grown for similar purposes in Brasil. In our conservatories, the cactuses are cultivated as ornamental plants alone, either for the beauty of their flowers or the singularity of their forms.

GROSSULARIACEÆ.—This is a well-known order, consisting principally of one genus, *Ribes*, which includes all the gooseberries and currants of our gardens. The species, of which there are upwards of eighty, are unarmed or thorny shrubs, with round or irregularly angled stems and branches; simple, lobed, alternate leaves, destitute of stipules and tendrils. The inflorescence is axillary and in racemes. The calyx, which is often coloured, is four or five cleft; petals, perigynous, equal in number to, and alternate with, the segments of the calyx; stamens, of the same number, alternate, and

inserted with the petals; filaments, distinct; anthers, two-celled, bursting longitudinally; ovary, one-celled, cohering with the tube of the calyx; ovules, indefinite; fruit, a berry, crowned with the remains of the flower, one-celled, filled with pulp with two parietal placentas; seeds, numerous, suspended among the pulp by filiform funicles; testa, externally gelatinous; albumen, horny.

The order is very conveniently grouped into two sections—namely, the Gooseberries, which have prickly stems, and the flowers either singly, or in clusters of not more than two or three; and the Currants, which are entirely without spines, and the flowers in racemes. There are a few species, such as *Ribes dracantha* and *saxatile*, which may be considered as intermediate, these having the spines and habit of growth of the one, and the racemose inflorescence of the other. The common gooseberry (*R. Grossularia*), the red currant (*R. rubrum*), the black currant (*R. nigrum*), and the flowering currant (*R. sanguineum*), are familiar examples of the order, and all too well known to require any detailed description. The gooseberry is found wild in many parts of Britain; and is reared in the north of England to greater perfection than in any other country, Lancashire prize-specimens having been known to weigh an ounce and a half.

Gooseberries and currants are well known as agreeable acid fruits, their acidity or sweetness depending upon the relative quantities of malic acid and sugar which they contain. They are used both as dessert and kitchen fruits; preserved with sugar, they make the best jams and jellies; and when fermented, produce wines little inferior to that of the grape. The blackberry has tonic and astringent properties, infusions of the leaves being used for this purpose. (See THE FRUIT GARDEN.)

SAXIFRAGACEÆ.—This order consists chiefly of very small herbaceous plants, with alternate or opposite leaves, and is readily distinguished by the peculiar ovary, which is more or less completely inferior, consisting of two carpels which diverge at the apex. As useful plants, they are unimportant, but they are the most charming that greet the eye of the botanist in his mountain rambles. *Saxifraga stellaris* and *S. aizoides* are the great ornaments of Highland streams at a low elevation; while higher up, the rocky banks are covered with a purple carpet of *S. oppositifolia*, or the rarer *S. rivularis*, which attracts many a botanist to the summit of Loch-na-gar. But it is not alone the Scottish mountains that are adorned with these 'alpine gems;' *S. Boussingaultii* reaches to nearly 16,000 feet on Chimborazo.

UMBELLIFERÆ.—This is one of the most extensive and important of the natural orders, comprising about

Hemlock.

300 genera, and above 1500 species. The genera, though presenting many minor differences, are, on the whole, well marked; so that no one who has seen the flower of the parsley and common hemlock can have any difficulty in detecting an umbelliferous plant. The species are for the most part herbs, seldom shrubs, with fistular furrowed stems, loving damp waste places, and varying much in their properties, according to the climate under which they are grown. The leaves are generally divided, sometimes simple; are alternate, and clasp the stem by a broad sheathing petiole. The flowers are white, pink, yellow, and blue, and in umbels, which are simple or compound, and these are with or without bracts at their base: when seated at the base of the umbel, the bract is called an involucre; when at the base of the umbellules in the compound head, an involucel. The calyx is superior and five toothed; petals, five, and inserted on the outside of a fleshy disc, which is placed on the top of the ovary; stamens, five, and inserted alternately with the petals; ovary, inferior, and two-celled, with pendulous ovules; styles, two, distinct; stigmas, simple. The fruit consists of two carpels, united by a common axis, from which they separate when ripe; the external part of the carpels is traversed by linear ridges, which are divided into primary and secondary, there being five of the latter, and four of the former, between them. The ridges are separated by channels, below which are often placed, in the covering of the seed, receptacles or vittæ of an oily matter. The seed is pendulous, usually cohering with the carpel, rarely loose.

Among the more familiar genera may be mentioned the parsnip (*Pastinaca*), the cow-parsnip (*Heracleum*), the celery (*Apium*), the carrot (*Daucus*), the hemlock (*Conium*), the cow-bane (*Cicuta*), and the coriander (*Coriandrum*). Several relations have been pointed out between the Umbelliferæ and other orders; such as their agreement with the Crowfoots in the sheathing leaves, the acrid juice, and large albumen; with some of the Geraniums in their habit, form of leaves, and poisonous properties; and with Ivyworts, from which they differ little, except in the parts of the flower.

The properties of this order are very variable and important. Generally speaking, all the genera are characterised by an acrid principle, which is well developed in the hemlock, rendering the roots of that plant virulently poisonous. This principle is more or less disposed throughout the whole order, but is often enfeebled by change of situation, or altogether destroyed by cultivation. Thus the wild plants from which garden celery and other esculents are derived, are poisonous. In like manner, Dr Christison has found a reputedly poisonous species of *Œnanthe* to be innocuous when grown in the neighbourhood of Edinburgh. Another important secretion is the aromatic oil contained in the vittæ of the pericarp, which is used in diet as a condiment, and in medicine as an aromatic and carminative. It is found abundantly in the anise, caraway, dill, cumin, and coriander. A gum-resinous exudation characterises others of the genera, which yield the valuable medicines asafetida, galbanum, opoponax, &c. The roots of many of the Umbelliferæ, when cultivated and properly treated, are replete with starch and sugar—as, for example, the common carrot, the parsnip, the skirret, and the arracacha of the South Americans.

LORANTHACEÆ.—These are parasitical plants, with stems and branches in articulations, which often fall to pieces in drying. They are chiefly natives of the equinoctial regions of Asia and America, but a few are European and African, and we have one British representative of the order in *Viscum album*, the 'misletoe bough' of Christmas times, which was held sacred by the Druids.

CAPRIFOLIACEÆ.—A well-known order, consisting of 12 or 14 genera, and about 220 species. They are erect or twining shrubs, rarely trees, having opposite, simple, or pinnate leaves, without stipules; and flowers terminal in corymbs, or axillary. The flowers are white,

scarlet, or yellow, and often sweet scented, as in the common honeysuckle.

The order has been divided into two sections—namely, the SAMBUCEÆ, or elder tribe, and the LONICERÆ, or true honeysuckle tribe. In the former, the corolla is regular and rotate, seldom tubular; ovary, three or four celled; style, none; stigmas, three, sessile; raphe on the inner side of the ovule. It includes the genera *Sambucus* and *Viburnum*. In the latter, the corolla is tubular, often irregular; style, one; berry, from two to four celled, each cell containing one or many seeds; raphe, on the outer side of the ovule. It embraces the genera *Caprifolium*, *Lonicera*, *Triosteum*, *Diervilla*, *Abelia*, *Symphoricarpus*, *Linnæa*, &c. As examples of the first tribe, may be mentioned the common elder (*Sambucus nigra*)—well known by its pinnate leaves and terminal cymes of white flowers, which appear in June; by its dark purple pulpy berries, which ripen in September; and by its yellow wood, with a light white pith; also the dwarf elder or danewort (*S. Ebulus*). The laurustin (*Viburnum Tinus*) is a well-known evergreen, whose showy white flowers appear during winter; and the Gueldres rose (*V. Opulus*) is common in gardens under the name of the 'snowball-tree.' In the Viburnums the leaves are not pinnate, and the wood is hard, and without the spongy pith of the elders. As examples of the second tribe, may be mentioned, the honeysuckles (*Lonicera*), the snow-berry (*Symphoricarpus*), and the graceful *Linnæa borealis*, named in honour of the immortal botanist. The Caprifoils grow chiefly in the temperate regions of the northern hemisphere, and delight in cool shady places.

The properties of the order are varied, and of considerable utility. The berries of the elder are fragrant and sudorific; they contain malic acid, and a wine is often made from them. The leaves are emetic and purgative; and the berries, in a green state, are poisonous to some animals. The wood, which is hard and yellow, is used by turners. The wood of the wayfaring-tree is said to be in great repute for the tubes of tobacco-pipes in some parts of Turkey; and the bark yields a viscous substance, used as birdlime. The roots of *Triosteum* and *Diervilla* are used in America instead of ipecacuanha; and the berries of *T. perfoliatum* are said to form no bad substitute for coffee. The honeysuckle is a purgative, but is cultivated principally as a handsome and fragrant climber. Indeed, the whole are grown more for their beauty than economical uses—the climbing species for adorning old walls and trunks of trees, and the upright sorts for their shelter and ornament in pleasure-grounds.

RUBIACEÆ.—This is a large, and in many respects not a well-defined order, composed of small trees, shrubs, and herbs. It has been proposed to separate it into two orders—CINCHONACEÆ, containing those plants most resembling cinchona; and GALIACEÆ, those most resembling the galiums or bedstraws. The *Cinchonaceæ* and *Galiaceæ* indeed form two well-marked groups of plants, abundantly distinct from each other in habit and in geographical distribution: the one consisting of trees, shrubs, and herbs, with opposite or verticillate leaves and interpetiolar stipules; almost exclusively inhabiting the hotter parts of the world, most of them eminently conspicuous for their economical products and the beauty of their broad foliage and flowers, although some of them are mean weeds; the other composed entirely of straggling herbaceous plants, with weak angular stems and narrow verticillate exstipulate leaves, inhabiting northern countries, and, with one or two exceptions, alike inconspicuous for use and ornament. Unfortunately, however, fructification does not supply any character whereby those two ideally distinct groups of plants can be clearly separated from each other, and in the limitation of natural orders something more than a difference of habit is considered requisite. The recent discovery of the peculiar axillary glands of *Cinchonaceæ* in *Galiaceæ* serves still further to break up the supposed distinctions between these groups. Decandolle has proposed a further subdivision into thirteen sub-tribes.

By far the greater number of the species are tropical plants, though many are amongst the most common and neglected of British weeds. Madder (*Rubia tinctorum*) is common in gardens, and is much cultivated in Belgium and Holland for its roots, which yield a rich brownish-red dye. The *Galiums* or bedstraws are familiar plants, growing on hedges, on dry banks, or sides of old ditches, and known by the common name of cleavers, ladies' bedstraw, crosswort, and the like. *Asperula odorata*, another of the order, is the well-known woodruff, which acquires, when dried, a most delicate fragrance. The coffee-tree (*Coffea*), Jesuit's bark (*Cinchona*), the Cape jasmine (*Gardenia*), and ipecacuanha (*Cephäelis*), are also well-known members.

The properties of the order are very varied. The roots of many, as the madders and bedstraws, contain a large quantity of colouring-matter; and it is said that fowls fed upon the roots of some plants of this order have their bones dyed of a red colour; in other cases, the plants are acrid, emetic, purgative, or diuretic. The bark (as that of the Cinchona, or Peruvian bark) is sometimes bitter, tonic, and astringent, and highly prized in intermittent fevers. Exertions have recently been made by Dr Anderson to introduce the cultivation of Cinchona to India, where the climate is highly suitable for the production of this important drug. The value of the roasted albumen of the coffee-berry is too well known to require allusion; and the fruits of others of the order have been recommended as answering the same purpose. Among our ancestors, the dried soft haulm of the galiums was much used for beds; hence the term 'bedstraws.'

COMPOSITÆ.—This is one of the most extensive of the natural orders, containing not fewer than 900 genera, and between 9000 and 10,000 species. The members are herbaceous plants or shrubs, with leaves alternate or opposite, without stipules, and usually simple. What is called the flower is an aggregation of unisexual or hermaphrodite *florets*, collected in dense heads upon a common receptacle, surrounded by an involucre, as exemplified in the common daisy, marigold, and dandelion. As the compound leaf is composed of a number of leaflets, so is the composite flower made up of a number of florets arranged on one receptacle, which is furnished with a calyx-like involucre. Each floret is complete in itself, having all the appendages of bracts, calyx, corolla, stamens, and pistil, although the calyx is in a much reduced state, appearing in the form of bristly hairs. The corolla is monopetalous, and either ligulate, tubular, or bilabiate—that is, has two equal lips cut into several lobes. The stamens are equal in number to the teeth of the corolla, and alternate with them; the anthers grow together, so as to form a kind of cylinder, through which passes the style, ending in a two-lobed stigma. The ovary is inferior, one-celled, with a single erect ovule. The fruit is an achene, which retains the pappus when ripe, and falls without opening; the appearance of this pappus or down is familiarly illustrated in the head of the ripe dandelion.

The Composite order has been divided into three sections:—1. *Cichoraceæ*, in which all the florets are ligulate and perfect. 2. *Corymbiferæ*, most of the florets tubular, all hermaphrodite, or those of the circumference filiform or tubular, and pistiliferous or ligulate; style, not jointed. 3. *Cynarocephalæ*, all the florets tubular; style, jointed. The Composite plants are widely scattered over the globe, forming, according to some authorities, one-twelfth of its vegetable productions. Humboldt states that they constitute one-seventh of the flowering-plants of France, one-eighth of those of Germany, one-fifteenth of those of Lapland, a sixteenth of those of New Holland, a sixth of the North American Flora, and one-half of that of America within the

tropics. Though their increase and decrease do not follow any law of climate, it may be stated generally that the Cichoraceæ are chiefly found in cold, and the Corymbiferæ in warm regions. The Composites are herbaceous in the colder quarters of the globe, and become shrubby as we approach the equator.

The Cichoraceæ are well illustrated by the common lettuce (*Lactuca*), the dandelion (*Taraxacum*), the succory (*Cichorium*), and the sow-thistle (*Sonchus*), which are common and familiar British plants. All the members of this section yield a milky juice, which is bitter, astringent, and slightly narcotic. Many of them are used in medicine—as the lettuce, from which the narcotic and diuretic *Lactucarium* is obtained. Many are also used as articles of food; thus, endive (*C. Endivia*) is employed as a salad; so is the garden lettuce when young, the root of the sonchus, and perhaps, more than all, the root of *C. Intybus*, or wild succory, which is roasted and largely mingled with coffee under the name of chicory. The Corymbiferæ, which have the central florets tubular, and the outer ones generally ligulate, are illustrated by the daisy

Chamomile.

(*Bellis perennis*), the chamomile (*Anthemis nobilis*), the groundsel (*Senecio*), the tansy (*Tanacetum vulgare*), the dahlia, marigold, &c. The juice of this section is watery; sometimes bitter and tonic, and sometimes acrid. Many of them contain volatile oils, which are used for various purposes, and some yield yellow and other dyes. Among the most useful of the section may be mentioned the Jerusalem artichoke, wormwood, chamomile, tansy, and arnica—the last much employed in homœopathic practice; indeed, most of the Corymbiferæ are of medicinal value. *Cynarocephalæ.*—The plants of this division are bitter and tonic. By cultivation, this bitterness is lessened, and they become edible. The section may be illustrated by the cardoon and common artichoke, all the thistles (*Carduus*), the burdock (*Arctium*), the corn bluebottles (*Centaurea*), the safflower (*Carthamus*). The properties of the artichoke are well known, as are also those of the carthamus, which is used in dyeing as well as in medicine. The thistle is chiefly interesting as being emblematical of Scotland; but neither antiquaries nor botanists have been able to discover with certainty the species entitled to the appellation of *the* Scotch thistle. *Onopordum Acanthium* adorns the grave of Burns in Dumfries, and is usually employed in national demonstrations; but Burns had another species in view as the 'bur-thistle'—namely, *Carduus lanceolatus*. Others prefer the milk-thistle; and so far as the figures on the coins of the Scotch kings indicate a special species, the milk-thistle appears to be the one.

VACCINIACEÆ.—This order contains two well-known genera—*Vaccinium*, the bilberries and whortle-berries; and *Oxycoccus*, the cranberries. They are humble shrubs, with alternate, leathery leaves, a close-growing bushy habit, and round or angled stems. The flowers are solitary, or in racemes, and in their general structure differ little from the heaths, except in the ovary being inferior. In Vaccinium, the stamens are eight or ten, and the anthers horned or spurred; in Oxycoccus, the stamens are eight, and the anthers without spurs. The members are natives of Europe and America; the former genus delighting in high dry situations, and the latter in marshes and swamps. Both yield edible berries, which have austere antiscorbutic properties. The bilberry or blaeberry (*V. Myrtillus*) of our woods and hills is familiar to every one, as also the whortleberry (*V. Vitis-Idæa*). In North America there are many species—as, *V. angustifolium* (bluets); *V. stamineum* (deer-berries); and *V. frondosum* (blue tangles). Of the cranberry there are two species—*O. palustris*, the common cranberry of European morasses; and *O. macrocarpa*, the American cranberry, which has a larger and more oblong fruit. The berry of both is extensively collected, and used for tarts and other conserves.

§ COROLLIFLORÆ.

In this section the flowers are dichlamydeous, the petals united into a tube, hypogynous, stamens inserted in the corolla (or in the first four orders arising directly from the receptacle). The plants may usually be recognised by the corolla appearing to consist of one piece, the petals being united (gamopetalous). Many of the orders have regular flowers, but a large number have them two-lipped, and therefore irregular, such as the Foxglove, labiate plants, and Acanthi.

The following are the orders contained in this section:—

*Ericaceæ—Heathworts.
*Pyrolaceæ—Winter-greens.
*Montropaceæ—Fir-rapes.
Epacridaceæ—Epacrids.
Ebenaceæ—Ebenads.
*Aquifoliaceæ—Holly order.
Sapotaceæ—Sapotads.
Myrsinaceæ—Ardisiads.
Jasminaceæ—Jasmines.
*Oleaceæ—Olives.
Salvadoraceæ—Salvadora order.
Asclepiadaceæ—Asclepiads.
*Apocynaceæ—Dogbanes.
Loganiaceæ—Strychnads.
*Gentianaceæ—Gentianworts.
Bignoniaceæ—Trumpet-flowers.
Gesneraceæ—Gesnerads.
Crescentiaceæ—Calabash-trees.
Pedaliaceæ—Pedalium order.
*Polemoniaceæ—Phlox order.
Hydrophyllaceæ—Water-leaves.
Diapensiaceæ—Diapensia order.
*Convolvulaceæ—Bindweeds.
*Cuscutaceæ—Dodders.
Cordiaceæ—Sebestens.
*Boraginaceæ—Borageworts.
Ehretiaceæ—Ehretia order.
Nolanaceæ—Nolana order.
*Solanaceæ—Potato order.
*Atropaceæ—Nightshades.
*Orobanchaceæ—Broom-rapes.
*Scrophulariaceæ—Figworts.
*Labiatæ or Lamiaceæ—Dead-nettles.
*Verbenaceæ—Verbenas.
Stilbaceæ—Stilbids.
Selaginaceæ or Globulariaceæ—Selagids.
Acanthaceæ—Acanthads.
*Lentibulariaceæ—Butterworts.
*Primulaceæ—Primulas.
*Plumbaginaceæ—Leadworts.
*Plantaginaceæ—Ribworts.

ERICACEÆ.—This is an extensive order of shrubs or under-shrubs, with leaves evergreen, rigid, entire, whorled, or opposite, and without stipules. 'The name of the heath family,' as it has been very appropriately remarked, 'conjures up immediately the image of a number of narrow-leaved plants, with globular, ventricose, or bell-shaped flowers; and we are apt at first to think that the family is so natural a one as to require very little explanation.' Did the order include only the heaths, this would be the case; for all the heaths, differing as they do in some particulars, may be recognised at a glance; but as the order includes the Rhododendrons, the Azaleas, and Kalmias, besides several other plants which have not so strong a family likeness to each other as the heaths, it becomes necessary to say a few words on the botanical resemblances which connect them together. The first and most striking of these is the shape of the anthers—each of which appears like two anthers stuck together—and the manner of their opening, which is always by a pore or round hole in the upper extremity of each cell. The filaments also in all the genera grow from beneath the seed-vessel, being

generally slightly attached to the base of the corolla. There is always a single style with an undivided stigma, though the capsule has generally four cells, each containing several small seeds. The calyx is four or five cleft, and the corolla is tubular, with a larger or smaller limb, which is also four or five cleft. The above are the connecting points between the various genera which compose the family; but the differences are such as, according to most botanists, to require a subdivision of the Ericaceæ into four sub-orders, or even into four distinct and independent orders. Adopting the former idea, we shall consider the heath family under the following subdivisions:—1. *Ericeæ*, or those most closely resembling the true heaths, their fruit being loculicidal, rarely septicidal or berried, and the buds naked; 2. *Rhododendreæ*, those allied to the Rhododendrons, their fruits being capsular septicidal; the buds, scaly, resembling cones; 3. *Pyroleæ*, those allied to the winter-green of our woods, and distinguished by having a minute embryo at the base of fleshy albumen, the two preceding having a cylindrical embryo in the axis of the albumen. 1. *Ericeæ.*—This sub-order may be arranged into two sections—namely, the true heaths (*Ericidæ*), having bracteal pedicels of flowers, the corolla of each flower being more or less bell-shaped or globose, with a four-cleft limb, a four-lobed calyx, and eight stamens; and the *Andromedidæ*, which have the corolla more globose, the limb five-cleft, the calyx five-lobed, and ten stamens. In other respects both sections are nearly alike; both have a honey-bearing disc, and both have the leaves, which are narrow and leathery, slightly rolled in at the margin. The stamens appear differently in the several genera; some being capitate, others ending in awn-shaped horns; in some they are concealed by the corolla, in others they are exposed. The style, in some of the genera, projects considerably beyond the corolla, in others it is rather contracted. The more familiar genera are, the common heath of our moors (*Erica tetralix*), common ling or heather (*Calluna vulgaris*), and the Cape heaths, many of which have glutinous, cylindrical corollas. All of these are true heaths, and bear so striking a resemblance to the common ling of our moors as to be at once recognised. The genera *Andromeda*, *Zenobia*, the strawberry-tree (*Arbutus*), the bearberry of our Highlands (*Arctostaphylos uva-ursi*), and *Gaultheria*, frequent in gardens, are illustrations of the second section. The heathworts cover large tracts of our own country, are common in North and South America, and abound at the Cape of Good Hope, which has supplied our gardens with hundreds of the most beautiful species. All of them possess bitter, astringent, and diuretic properties; and the berries of some, as well as the flowers, have been used in dyeing. The Arbutus is a very ornamental shrub, the berries of which are edible, and may be used in the preparation of a wine. The Picts are said to have derived a wholesome beverage from the heath; and the bearberry plant is used in some parts of Russia for tanning. The Highland heath furnishes excellent pasture for bees, and its shoots furnish the principal food of the grouse. 2. *Rhododendreæ.*—The plants in this sub-order have all less or more a resemblance to the well-known genus *Rhododendron*, the species of which have generally evergreen leaves, and large showy flowers produced in terminal corymbs. The calyx is small; the corolla, large in proportion, bell-shaped, and deeply five-cleft; the stamens, five or ten; the capsule, five-celled, and five-valved. The flowers are generally purple or whitish, though in some they are yellow, pink, or bright scarlet, as in the Nepaul tree-rhododendron (*R. arboreum*). The genus *Azalea* is very nearly allied to the rhododendron; but its species—the Indian and American—differ considerably in their inflorescence and leaves; the latter in some species being deciduous. *Kalmia* and *Menziesia* are familiar garden genera; *Ledum palustre*, or wild rosemary, and the Labrador tea-plant (*L. latifolium*), also rank under this section, whose members have an extensive range, being found abundantly in Europe, Asia, and North America. They are chiefly inhabitants of high cold regions, and in this particular agree with the general habit of the order. The Rhododendra possess soporific properties—*R. crysanthum* being used in gout and acute rheumatism. The Azaleas are astringent, and some yield a poisonous honey, well distinguishing these plants from the true heaths, none of which are poisonous. The honey which gave rise to symptoms of poisoning in the Greek soldiers during the celebrated Retreat of the Ten Thousand mentioned by Xenophon, was obtained from *Rhododendron ponticum* and *Azalea pontica*, two ornamental shrubs much cultivated in our gardens and shrubberies. The late Colonel Madden observed, that the leaves and flowers of *R. arboreum*, in like manner, poisoned the cattle which partook of them in Kumaon. Other species are poisonous, while some yield a resinous matter having a powerful and oppressive odour. *R. setosum* is the *Tsalu* of the Sikkim Bhoteas and Tibetians, who attribute the oppression and headaches attending the crossing of the loftiest passes of the Eastern Himalaya to the strongly resinous odour of this and *R. anthopogon*, the *Palu* of the natives. The Rhododendrons recently introduced by Dr Hooker from Sikkim form the most valuable addition to our ornamental plants that has been made for many years. *R. nivale*, which occurs at elevations of from 16,000 to 18,000 feet on the Tibetan frontier, is thus described: 'The latest to bloom, and earliest to mature its seeds, by far the smallest in foliage and proportionably largest in flower, most lepidote in vesture, humble in stature, rigid in texture, deformed in habit, yet the most odoriferous, it may be recognised, even in the herbarium, as the production of the loftiest elevation on the surface of the globe—of the most excessive climate—of the joint influences of a scorching sun by day, and the keenest frost at night—of the greatest drought followed in a few hours by a saturated atmosphere—of the balmiest calm alternating with the whirlwind of the Alps. For eight months of the year it is buried under many feet of snow; for the remaining four it is frequently snowed and sunned in the same hour.' 3. *Pyroleæ.*—This sub-order is well illustrated by the winter-green (*Pyrola*), which is common in British woods. The species of Pyrola are described as 'pretty little evergreen plants, with white flowers, the corollas consisting of five distinct petals, and which have ten stamens, the anthers of which are two-celled, each cell opening by a pore: the style is single, ending in a capitate stigma cut into five lobes; the fruit, a five-celled capsule.' They are chiefly objects of interest to the practical botanist.

OLEACEÆ.—Under this order are reckoned upwards of 20 genera, and about 130 species. They are trees and shrubs with erect or climbing stems, and with leaves opposite, petiolate, simple, seldom ternate or pinnate, and destitute of stipules. The inflorescence is often paniculate; the flowers regular, and sometimes, by abortion, polygamous; calyx, free, divided, and persistent; corolla, hypogynous, four-cleft, and rarely wanting; stamens, two, alternating with the lateral lobes of the corolla when present, or when there are four petals connecting the lateral petals in pairs; filaments, free; anthers, two-celled, bursting longitudinally; ovary, free, two-celled; ovules, pendulous and in pairs; style, sometimes wanting; stigma, entire or bifid; fruit, fleshy or dry, sometimes one-celled by abortion. According to the character of the fruit, the order is sometimes subdivided into the OLEÆ, having it a drupe or berry, and the FRAXINEÆ, having it samaroid.

The principal genera are—*Olea*, the olive; *Fraxinus*, the ash; *Ornus*, the manna-ash; *Ligustrum*, the privet; *Syringa*, the lilac; *Chionanthus*, the fringe-tree; and *Phillyrea*. The olive (*O. Europæa*) is a well-known tree, with small white flowers, and a fleshy drupe like a sloe, from which is expressed the olive oil of commerce. The

ash (*F. excelsior*) is a common British tree, with pinnate leaves, the flowers without a corolla, and the fruit a winged samara or key, with one or two seeds. The manna-ash (*Ornus Europæus*), though closely resembling the common ash in its leaves and samara, has loose panicles of white flowers, the corollas of which are divided into four long narrow segments. The privet (*Ligustrum vulgare*), the lilac (*Syringa vulgaris*), and Phillyrea, are too common ornamental shrubs to require particular notice.

Economically, the oliveworts are of great importance. Besides the oil of the olive, so universally used in Europe, the unripe berries are pickled and eaten on the continent to provoke an appetite; and the bark, which is bitter and astringent, is used as a substitute for cinchona. The bark of the common ash, as well as that of several others, is astringent and febrifugal, while the wood of the former is easily worked, and exceedingly tough and durable. What is in the present day called manna is a saccharine cathartic, procured by wounding the bark of the Ornus, &c. The sweetness of this substance is not due to the presence of sugar, but to a distinct principle called Mannite, which differs from cane-sugar in not fermenting with water and yeast. The lilac, like the ash and others, is held in great repute in some of the marshy districts of France as a febrifuge, being indeed the only remedy ever employed for the marsh or intermittent fever which prevails there. The flowers of *O. fragrans* are said to be employed by the Chinese to impart a delicate flavour to some of their teas.

APOCYNACEÆ.—Trees or shrubs, usually with milky juice, and characterised by their peculiar hour-glass-like stigma. It contains about 600 species. *Vinca minor* is a familiar British representative, being one of the prettiest wild-flowers of our woods; while more gorgeous species of *Allamanda* and *Nerium* luxuriate in warmer regions. *Cleghornia*, and many others, occur in India. Mr Paul speaks of the *Nerium Oleander* as the great ornament of the banks of the Jordan, where he observed it in 1856 in immense profusion. The remarkable structure of its stomata is described under VEGETABLE PHYSIOLOGY (p. 71), but all the order do not present this peculiarity. Its wood is poisonous, and has proved fatal when used as skewers in camp-cooking.

LOGANIACEÆ.—This order consists chiefly of woody plants, with opposite entire, stipulate leaves, natives of the tropics. It is chiefly remarkable from containing *Strychnos Nux-vomica*, the plant from which strychnine is prepared. It is called rat's-bane, poison-nut, or koochla. This tree abounds on the Malabar and Coromandel coasts of the Indian peninsula, and produces a small orange-like fruit full of pulp, in which the seeds are imbedded. The latter alone form the fatal drug; but the wood of the tree is intensely bitter, and is employed in the cure of intermittent fevers and the bites of venomous snakes. Strychnia, the alkaloid upon which the poisonous properties of the seeds depend, is an intensely bitter substance—so bitter, says Johnston, that its taste can be detected when dissolved in 600,000 times its weight in water. This has led to its use in the adulteration of malt liquors, and there is reason to believe that it is still used for this purpose. *S. toxifera*, another species, is employed by the Red Indians to poison their arrows, which thus cause immediate death when introduced into the slightest wound. *S. Tieuté* yields the upas radja of Java, not that half-mythical upas around which so many fearful *fables* have been entwined.

CONVOLVULACEÆ.—A well-defined order, containing above 40 genera, and between 600 and 700 species. The members are lactescent herbaceous plants or shrubs, with stems usually twining, and with leaves alternate, undivided or lobed, and exstipulate. The inflorescence is axillary or terminal; peduncles one or many flowered, the partial ones generally with two bracts; calyx, persistent in five divisions, and imbricated as if in more whorls than one—often very unequal; corolla, monopetalous, hypogynous, regular, deciduous; the limb, five-lobed and plaited; stamens, five, inserted into the base of the corolla, and alternate with its segments; ovary, free, with two or four cells; the ovules, definite and erect; style, one, usually divided at the top; stigmas, obtuse or acute; capsule, with the valves fitting at their edges to the angles of a loose dissepiment, bearing the seeds at its base; seeds, large; albumen, mucilaginous.

The more familiar genera are *Convolvulus* and *Ipomœa*, which have the corolla marked with a decided fold or plait, peculiarly imbricated calyx, and are climbing plants, not easily confounded with any other family. The *Convolvulus arvensis* is the wild climber of our hedges; and *C. tricolor*, so common in gardens, is a native of Sicily. The bindweed (*Convolvulus Sepium*) is another of our hedge-natives, and is a well-known pest of the farm.

The roots of the order abound in an acrid, purgative, milky juice, exemplified in *jalap*—which is obtained from *Exogonium Purga*—and in *scammony*, the concrete juice of the root of *Convol. scammonia*, the roots or tubers of *Convolvulus Batatas*, the common sweet potato, are edible, as are also those of *Ip. macrorhiza*, whose insipid farinaceous tubers are found in the sandy soil of Georgia and Carolina, weighing as much as forty or fifty pounds.

CUSCUTACEÆ.—These plants are parasitical, and are very destructive to flax and clover crops in England, some of them having been originally introduced with the seed of these crops from Odessa and elsewhere.

BORAGINACEÆ.—The plants of this order are chiefly herbaceous, have round stems, alternate rough leaves, and flowers in scorpioidal cymes. Corolla, usually regular and five cleft, imbricate, often with faucial scales. Fruit, two or four distinct achenes; seeds, exalbuminous. Some of the plants of the order yield dyes, such as the alkanet, others form pot-herbs; one maritime species (*Stenhammaria*) is a vegetable substitute for oysters, having, it is said, a similar flavour; and another (*Symphytum asperrimum*) is particularly recommended by agricultural writers as a suitable food for pigs. More sentimental associations surround the forget-me-not (*Myosotis palustris*), which is not uncommon in marshy situations in many parts of Britain.

NOLANACEÆ, SOLANACEÆ, ATROPACEÆ.—These three groups have, until lately, been associated under one order; and although tabulated separately, we shall save space by discussing their characteristics together, for they have many points of structure in common. They are herbaceous plants or shrubs, with alternate leaves, and with angular or rounded stems; calyx, five (rarely four), parted and persistent; corolla, with the limb having the same number of lobes as the calyx, somewhat unequal, and deciduous; estivation, folded or imbricate; stamens, alternating with the segments of the corolla, sometimes one abortive; anthers, bursting longitudinally, or by terminal pores; ovary, two or more celled, rarely one-celled; ovules, usually indefinite; style, continuous; stigma, obtuse, very rarely lobed; fruit, either a capsule opening variously, a berry with the placenta adhering to the dissepiment, or a nuculanium, with five spurious-celled nucules, which have one seed in each; seeds, sessile.

The *Solanaceæ* closely resemble each other in their flowers, of which those of the garden nightshade and potato may be taken as examples; and also in their berry-like fruit, which is always crowned by the persistent calyx; seeds, albuminous; embryo, curved. The genus *Solanum*, to which belongs the bitter-sweet (*S. Dulcamara*), the garden nightshade (*S. nigrum*), and the potato (*S. tuberosum*), has the anthers opening by two pores like the heaths; whereas all the other members have a slit down each cell, as the tomato, or love-apple (*Lycopersicum esculentum*), with its edible fruit; the capsicum (*C. frutescens*, &c.), whose dry inflated berry yields the cayenne-pepper of commerce;

and the winter-cherry (*Physalis Alkekengi*), also with edible berry-like fruit. To the *Atropaceæ* belong the deadly nightshade (*Atropa Belladona*), which furnishes the deadly poison of that name; and the Barbary or box-thorn (*Lycium barbarum*). They are dangerous in their qualities, the leaves and flowers being narcotic and poisonous. They are distinguished from the preceding by the imbricated estivation of the corolla, and their fruit is usually capsular and hard when ripe, and not soft and pulpy like a berry. The flowers are also more funnel-shaped, with a longish tube and spreading limb. The principal genera are—*Nicotiana N. Tabacum*, being the Virginian tobacco of commerce; *Petunia*, which furnishes some of our best known garden favourites; *Nierembergia*, a genus of ornamental green-house plants; *Hyoscyamus*, the poisonous henbane; *Datura*, *D. Stramonium*, being the common thorn-apple; and *Brugmansia* and *Salpiglossis*, all more or less prized for their showy funnel-shaped flowers, some of which are highly fragrant. The plants of this order display marked narcotic properties, and cause dilatation of the pupil: according to Dr Anderson, the true Solanaceæ do not cause dilatation. *Nolanaceæ*.—'This tribe,' says Mrs Loudon, 'is principally known by the genus *Nolana*, the species of which are annual plants, natives of Chili and Peru, which have of late been much cultivated in British gardens. The flowers of *N. atriplicifolia*, one of the commonest kind, very much resemble those of the *Convolvulus tricolor*, and the leaves are large and juicy like those of the spinach. On opening the corolla there will be found five stamens, surrounding four or five ovaries, which are crowded together on a fleshy ring-like disc. These ovaries, when ripe, become as many drupes, enclosing each a three or four celled nut, which is marked with three or more grooves on the outside, and has three or more little holes beneath. All the species of Nolana have the same peculiarities in their seed-vessels, though they differ in many other respects.'

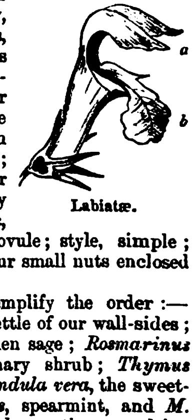
SCROPHULARIACEÆ.—The Figworts, of which the common foxglove may be taken as the type, form rather an extensive order, consisting of about 170 genera, and 1800 species. The members are herbaceous, rarely shrubby plants, with round or square stems; the leaves being simple and exstipulate, opposite or whorled, seldom alternate, and either sessile or with footstalks. The inflorescence is very variable, being axillary or united, usually in spikes, racemes, or in panicles; calyx, inferior, persistent, and often unequal; corolla, tubular or inflated, with a short limb, which is flat or erect, nearly equally divided, or labiate; stamens, definite, two or four; filaments, free; anthers, two-celled; ovary, two-celled and many-seeded; style, simple; stigma, obtuse, rarely bifid; fruit, a dry capsule.


Foxglove.

The following genera may be mentioned as illustrative of the order:—*Scrophularia*, weeds common in British ditches; *Digitalis*, the foxglove of our waysides and gardens; *Antirrhinum*, the well-known snap-dragon; *Linaria*, the toad-flax of our hedges and banks; *Euphrasia*, the eyebright; *Veronica*, including the brooklime of our ditches, and the speedwells, which abound in every waste place; *Rhinanthus*, the yellow rattle; and *Calceolaria*, *Buddlea*, *Mimulus*, and others, now favourites in every flower-garden. The form of the flowers in the different genera varies considerably, as may be seen by examining the foxglove, the speedwell, and calceolaria—plants at the command of every one. The stamens also present considerable differences: in the foxglove (*Digitalis purpurea*) there are two long and two short; in *Pentstemon* there are five, the fifth being long and slender, and without an anther; in *Calceolaria* and *Veronica* there are only two. Various attempts have been made to subdivide the order—as, for example, into two sections, the one including the genera having four anther-bearing stamens, and the other those having only two-anthered stamens. Mr Bentham divides it into three sub-orders, according to the inflorescence, each of which is again subdivided into several tribes.

In their properties, the members of this family present no great uniformity. The majority, however, contain a principle more or less acrid, purgative in some, and poisonous, as in the foxglove, unless taken in small doses. The meadow eyebright (*Euphrasia officinalis*) is slightly astringent and aromatic, without the deleterious qualities of the other genera. Cows are said to be fond of *Melampyrum pratense;* and Linnæus says the best and yellowest butter is made where it abounds. One or two species of Linaria and Calceolaria are named as yielding colours for the dyer. *Mimulus luteus* affords an interesting example of an exotic plant—from America—becoming speedily diffused throughout Europe in a naturalised state. It is now not uncommon in ditches. Its stigma, formed of two lips, displays peculiar irritability.

LABIATÆ.—A very large natural order, remarkable for the uniformity of structure and properties which prevails among the members. The *labiate* or lipped corolla immediately suggests the mint, sage, thyme, dead-nettle, horehound, and lavender, with which every one must be more or less familiar. They are herbs or under-shrubs, with quadrangular stems, and opposite, divided or undivided, exstipulate leaves, replete with receptacles of aromatic oil. The flowers are in opposite, nearly sessile, axillary, verticillasters, resembling whorls, as in the dead-nettle; sometimes solitary; calyx, tubular and persistent; corolla, bilabiate, the upper lip (*a*) being entire or bifid, the lower (*b*) three-cleft, the upper in estivation overlapping the lower; stamens, four, didynamous, the upper sometimes wanting; ovary, deeply four-lobed, seated on a fleshy disc, each lobe containing one erect ovule; style, simple; stigma, bifid; fruit, from one to four small nuts enclosed within the persistent calyx.



Labiatæ.

The following plants well exemplify the order:—*Lamium album*, the white dead-nettle of our wall-sides; *Salvia officinalis*, the common garden sage; *Rosmarinus officinalis*, the well-known rosemary shrub; *Thymus vulgaris*, the garden thyme; *Lavandula vera*, the sweet-scented lavender; *Mentha viridis*, spearmint, and *M. piperita*, peppermint; *Nepeta Glechoma*, the ground ivy of our woods and hedges; *Marrubium vulgare*, the true medicinal horehound; *Ballota nigra*, black horehound, well known for its heavy oppressive smell; *Prunella vulgaris*, self-heal; *Ajuga reptans*, the common bugle of our woods and shady situations; with basil, marjoram, betony, hyssop, and other culinary and medicinal herbs.

ACANTHACEÆ.—There are nearly 100 genera enumerated under this order, and upwards of 1400 species of herbs and shrubs, principally inhabiting tropical regions. Leaves, opposite, and without stipules; inflorescence, terminal or axillary; flowers, showy, in spikes with two or three bracts to each; calyx, in four or five divisions, and persistent—but in many of the species inconspicuous or obsolete, its place being supplied by the large bracts; corolla, monopetalous, and usually irregular, with the limb ringent or bilabiate, and deciduous; stamens, two or four, and in the latter case didynamous;

anthers, one or two celled, sometimes bearded, as in Acanthus, and bursting longitudinally; style, simple; stigma, one or two lobed; fruit, a two-celled capsule, elastically two-valved; seeds, supported on a filiform podosperm. The elastic dehiscent capsules, wingless seeds with hooked dissepiments, and imbricated flowers, are distinguishing features.

Examples of the genera are—*Acanthus*, *Thunbergia*, *Goldfussia*, *Lankesteria*, *Ruellia*, and *Justicia*. The species of Acanthus are found chiefly in the south of Europe; they are plants with graceful foliage, and the leaves of the *A. mollis* is said to have furnished Callimachus with patterns for the capital of the

Acanthus.

Corinthian pillar. The corolla varies considerably in the different genera; being bilabiate in Justicia, funnel-shaped in Ruellia, and campanulate in Thunbergia, the species of which are exotic climbers.

The properties of the order are little known. The Arabs use the leaves of an Acanthus by way of salad; *Justicia pectoralis*, boiled in sugar, yields a sirup used in the West Indies as a stomachic; and *J. paniculata* is said to be the basis of the famous French tonic, *Drogue Amère*. A valuable deep blue dye is said to be obtained from one of the East Indian Ruellias. Some of these, as well as the Justicias, are cultivated as exotic ornamental plants.

MONOCHLAMYDEÆ.

The plants in this division have either no floral envelope, or have one only. In the former case, the pistil and stamens are naked; in the latter, they are surrounded by a calyx, there being no parts corresponding to the petals of a true corolla. The following are the orders :—

ANGIOSPERMÆ.

Nyctaginaceæ — Marvel of Peru order.
*Amaranthaceæ—Amaranths.
*Chenopodiaceæ—Goosefoots.
Basellaceæ—Basella order.
*Scleranthaceæ—Knawel order.
Phytolaccaceæ—Phytolaccads.
Petiveriaceæ—Petivera order.
*Polygonaceæ—Buckwheats.
Begoniaceæ—Begoniads.
Lauraceæ—Laurels.
Atherospermaceæ — Plume Nutmegs.
Myristicaceæ—Nutmegs.
Monimiaceæ—Monimia order.
Proteaceæ—Protea order.
*Elæagnaceæ—Oleaster.
Penæaceæ—Penæa order.
*Thymelæaceæ—Mezereons.
Aquilariaceæ—Aquilaria order.
Chailletiaceæ—Chailletia order.
Samydaceæ—Samyda order.
Homaliaceæ—Homalium order.
*Santalaceæ—Sandal-woods.
*Aristolochiaceæ—Birthworts.
Nepenthaceæ—Pitcher plants.
Datiscaceæ—Datisca order.
*Empetraceæ—Crowberries.
*Euphorbiaceæ—Spurgeworts.
Scepaceæ—Scepa order.
*Callitrichaceæ—Starworts.
*Ceratophyllaceæ—Hornworts.
*Urticaceæ—Nettleworts.
Artocarpaceæ—Bread-fruits.
*Ulmaceæ—Elms.
Stilaginaceæ—Stilago order.
Lacistemaceæ — Lacistema order.
Podostemonaceæ—River-weeds.
Chloranthaceæ—Chloranthads.
Saururaceæ—Lizard's tails.
Piperaceæ—Peppers.
*Myricaceæ—Gales.
*Salicaceæ—Willows.
Liquidambaraceæ—Liquidambars.
*Betulaceæ—Birches.
*Corylaceæ—Hazels and Oaks.
Casuarinaceæ—Beefwoods.
Platanaceæ—Plane-trees.
Juglandaceæ—Walnuts.
Garryaceæ—Garrya order.
Rafflesiaceæ—Rafflesia order.
Cytinaceæ—Cistus Rapes.
Balanophoraceæ—Balanophora order.

GYMNOSPERMÆ.

*Coniferæ — Pines or Cone-bearers.
*Taxaceæ—Yews.
Gnetaceæ—Jointed Firs.
Cycadaceæ—Cycads.

Chenopodiaceæ. — Chiefly herbs with herbaceous (greenish) flowers. The embryo is coiled round mealy albumen or spiral without albumen; ovary, free, one-celled; stamens, inserted into the base of the perianth. Many of the species are used as pot-herbs, such as Spinach, Orach, and English mercury (*Chenopodium Bonus-Henricus*). The Beet (*Beta vulgaris*) yields a large proportion of sugar, and in the form of mangel-wurzel is an important forage plant throughout Europe.

Polygonaceæ.—Chiefly herbaceous plants, with large leaves; fruit, a triangular nut; exemplified by the common dock (*Rumex*). Buckwheat (*Fagopyrum esculentum*) is cultivated in Britain as food for pheasants; and various species of *Rheum* yield rhubarb. *R. palmatum* appears to be the plant which yields the best Turkey or Russian rhubarb.

Lauraceæ.—An important order, comprising about 450 species. They are tropical trees, with elegant foliage and aromatic properties, having exstipulate, alternate (seldom opposite) leaves, with inconspicuous flowers. The perianth is from four to six cleft, the limb sometimes obsolete; estivation, imbricate. The male and female flowers are distinct; the former have four, six, or eight stamens, opposite the segments of the perianth; the latter have four or more abortive stamens, furnished with glands, but without anthers, a one-celled, one-seeded ovary, with a simple style and an obtuse-crested stigma. The fruit is fleshy and indehiscent, naked, or covered by the enlarged and fleshy perianth. The two or four celled anthers, with the valves curling upwards when ripe, like those of the berberry, and the filaments furnished with kidney-shaped glands at their base, are peculiar characteristics of the order.

The chief genera are—*Laurus*, the sweet bay; *Sassafras*, the sassafras-tree; *Persea*, the avocado-pear; *Camphora*, the camphor-tree; *Cinnamomum*, the cinnamon-tree (all of which were at one time included under the genus Laurus); *Cassytha*, *Tetranthera*, and *Cryptocarya*. The true laurels have two anthers, and naked fruit; the cassia, cinnamon, and camphor have four anthers, and the fruit covered. The plants contain essential oil in abundance, which imparts to them a peculiar sweet, though strong penetrating odour, and a warm and pleasant taste; hence they yield some of our most grateful stimulants and spices. Cinnamon, cassia, camphor, benzoin, and sassafras, are products of the family; the roots of the sweet bay yield a violet dye; and a concrete oil, used in candle-manufacture, is obtained from the fruit of *Laurus glauca*. The custom of crowning heroes and scholars with the leaves of the bay or laurel is well known to every reader of ancient history.

Aristolochiaceæ.—There are only six or eight genera in this order, the members of which are herbaceous plants or shrubs, of climbing habit. The characters are—flowers, hermaphrodite; perianth, tubular, adherent with the ovary, and divided into three segments; stamens, from six to twelve epigynous, sometimes free and distinct, in other cases adhering with the style and stigma; ovary, three to six celled; style, short; stigma, six-rayed; fruit, capsular, dry, or succulent, three to six celled, and many-seeded; seeds, thin, flat, and of a dark-brown colour.

The chief genera are—*Aristolochia*, the birthwort; and *Asarum*, the wild-ginger of North America. Many of the species are natives of Europe; but they abound

in the tropical regions of America; *Arist. Clematitis* and *Asar. Europæum* are the only two found in Britain.

Aristolochia.

The birthworts are heating and stimulating in their properties, and act chiefly on the skin and kidneys. The prepared root of *Arist. serpentaria* (Virginian snake-root) is used in ague, typhus fever, and in gout—being one of the ingredients of the celebrated Portland powder. The snake-root, as the name implies, is regarded as an antidote against serpent-bites; but whether it is or not, there can be no doubt that a drop or two of the juice, if introduced into the mouth of one of these reptiles, has the power of stupifying it, so that it can be handled with impunity; and a few drops swallowed, almost instantly causes death. The roots of the species of *Asarum* partake more of bitter and acrid properties, and have a disagreeable odour like that of the stapelias. *Asarum canadense* has an aromatic flavour, and is often used by the country people in lieu of the true ginger.

EUPHORBIACEÆ.—In Britain, this order is represented by the small weedy spurges of our gardens and waste grounds, but exhibits a nobler aspect in hot regions, where the tall cacti-like columnar species attain gigantic proportions. The juice is usually acrid and milky, and the fruit formed of three globose carpels in union. The purgative resin Euphorbium is supplied by *E. officinarum* and other species. *Hura crepitans* is the sandbox-tree, whose fruit bursts with a loud noise. *Ricinus communis* yields castor-oil. The vegetable tallow of China, which has recently been introduced to European commerce, is derived from *Stillingia sebifera*. The seeds are beaten down and boiled to separate the tallow, which fuses at 80°, and is used for candles.

URTICACEÆ—ARTOCARPACEÆ.—These are extensive orders of plants, which, to the uninitiated, may appear very dissimilar—as illustrated, for example, by the common nettle, the hop, the hemp, the pellitory of the wall, the breadfruit-tree, the cow-tree, upas, mulberry, common fig, banyan, and India-rubber tree, all of which, though exhibiting different habits and products, are not only strikingly alike in their essential characters, but also in their general properties. They are much simplified by subdivision into two orders—namely, *Urticaceæ* and *Artocarpaceæ*—the former including the herbaceous species—as the nettle, hemp, and hop, with watery juice; and the latter the ligneous species—as the bread-fruit, mulberry, and fig, which have their juice milky. Bearing this distinction in mind, the following may be stated as the characteristics common to both:—Trees, shrubs, or herbs, with alternate leaves, sometimes covered with asperities or stinging hairs, and furnished with membranous stipules, which are deciduous or convolute in vernation; flowers, usually monœcious, sometimes diœcious; perianth, membranous, lobed, and persistent; stamens, definite, distinct, inserted into the base of the perianth, and opposite its lobes; anthers, turned backwards with elasticity when bursting; ovary, superior, simple; ovule, solitary, erect, or pendulous; stigma, simple; fruit, a simple indehiscent nut, as in the nettle and hemp—or consisting of achenes immersed in a fleshy receptacle, or the persistent fleshy perianths, as in the bread-fruit, or enclosing them within its cavity, as in the fig. 'The unisexual flowers,' says Dr Lindley, 'simple lenticular fruit, and superior radicle and stipules, afford the essential characteristics of this order, which cannot well be mistaken for any except *Chenopodiaceæ;* and the plants of that order never have stipules, or rough or stinging leaves.'

The chief genera in the order URTICACEÆ are—*Urtica*, of which *U. dioica* is the common stinging-nettle of our old wall-sides; *U. urens*, the smaller stinging-nettle; and *U. pilulifera*, the Roman nettle of our gardens; *Humulus lupulus*, the cultivated hop; *Cannabis sativa*, the fibrous hemp of commerce; and *Parietaria erecta*, the pellitory of the wall. The members of this order are widely scattered over the world, and increase apparently with the progress of civilisation; some of them—as, for example, the nettles—following in the footsteps of man. The chief genera of the order ARTOCARPACEÆ are—*Artocarpus*, of which *A. incisa* is the far-famed bread-fruit of the South Sea Islands; and *A. integrifolia*, the jack-tree of the East India Islands; *Galactodendron utile*, the cow-tree or palo de vaca of South America; *Antiaris toxicaria*, the upas-tree of Java, about which so many fabulous stories have been told; *Morus*, of which *M. nigra* is the common black mulberry, *M. rubra*, the red, and *M. alba*, the white mulberry, the leaves of which are so much esteemed for feeding silk-worms; *Ficus*, of which *F. Carica* is the common edible fig, *F. Sycamorus*, the sycamore fig, the wood of which is very durable, and is supposed to have been used in the construction of mummy cases; *Urostigma*, of which *U. Indica* is the spreading banyan, and *U. elasticum*, the India-rubber tree. *Bœhmeria* (*Urtica*) *nivea*, the China nettle, is the source of that beautiful fabric for handkerchiefs, &c., which has of late years come into use under the name of China-grass and China nettle-fibre. Experiments at Kew have shewn the plant to be unsuitable for our climate; but large quantities of the fibre are produced in the East, and find a ready sale in European markets, and especially among European residents in hot countries, for whose clothing this extremely fine fibre is peculiarly adapted.

The Urticaceæ have watery juice, which is acrid and astringent, and the fibres of their stems are all less or

Hop.

more tenacious. The leaves of the hemp are narcotic; the hop has bitter, aromatic, and stomachic properties,

and its effluvia are also said to be narcotic. The stinging property of the common nettle is well known. In the Artocarpaceæ, the juice is milky, and on exposure to the air, becomes tough and elastic. Their fruit is edible, but their juice is generally acrid and poisonous; except in that of the Galactodendron, which is wholesome and nutritious. The elaboration of a tough elastic product seems to be characteristic of the whole order—making its appearance in the stem of the hemp, in the inspissated juice of the India-rubber tree, or in silk, the best of which is derived from silk-worms which feed on the leaves of the mulberry. Hemp, hops, silk, caoutchouc, figs, mulberries, and bread-fruits may be regarded as the most valuable products of the order.

Betulaceæ.—A small order of trees and shrubs, abounding in the temperate and colder regions of the globe. They have alternate simple leaves, with the primary veins often running straight from the midrib to the margin, and deciduous stipules. The flowers are in catkins, unisexual, and monœcious; the males having small scales in place of a perianth, or, in Alnus, a four-leaved membranous perianth. Stamens distinct, opposite the scales, scarcely ever monadelphous; anthers, two-celled; ovary, two-celled; ovules, definite, pendulous; style, single or none; stigmas, two; fruit, membranous, indehiscent, by abortion one-celled; seeds, pendulous, naked.

The chief genera are—*Betula*, the birch, and *Alnus*, the alder, the species of which abound in every northern country. The common white birch (*B. alba*) is an elegant tree, thriving in almost any sort of soil, and becoming stunted and dwarfish only in the arctic regions, or at great elevations. The weeping-birch is a still more graceful tree, grown in lawns and parks for its fine drooping branches and neat foliage. *B. nana* is the dwarf birch of high and exposed situations, being found on the Scottish mountains and in some countries approaching to the very limits of perpetual snow. *B. nigra* is the black birch of North America, the timber of which is used so much by cabinetmakers; and *B. papyracea* is the paper birch, whose bark is used by the Esquimaux and others in the construction of canoes. The common alder (*A. glutinosa*) is a quick-growing tree, found in swampy flats and by the borders of streams; its wood resists well the action of water, and is useful for piles; the Rialto at Venice is built on alder-piles, as well as many houses in Amsterdam; the hoary alder (*A. incana*) is seldom found south of the sixtieth parallel; the notch-leaved alders (*A. sinuolata* and *A. glauca*) are both American species.

The bark of the order is astringent and bitter, and has been used with effect as a febrifuge. A decoction of birch-bark is used by the Laplanders in the preparation of reindeer-skins; and the empyreumatic oil derived from it is said to be used by the Russians in tanning—hence the peculiar odour of their leather. The sweetish sap obtained by tapping the birch in spring is the chief ingredient in birch-wine; the leaves, which, when young, are highly odorous, are also used in imparting dyes of various shades of yellow. The wood of several of the birches is used in furniture-making and turning, and makes no mean substitute for mahogany. The wood of the alder is soft and white, and is used by turners and veneerers.

Corylaceæ.—The Corylaceæ or Cupuliferæ are so named from the cup-like shape of the persistent involucre in which their fruit or nuts are placed—as, for example, the acorn. The order includes many genera of well-known trees and shrubs—as the oak, chestnut, beech, hazel, and hornbeam. Their leaves are alternate, simple, and stipulate; their venation well marked, and often rigid; flowers, unisexual; the males in catkins, and the females in clusters or in catkins; the male flowers have from five to twenty stamens inserted into the base of the scales, or of a membranous perianth, generally distinct; in the females, the ovaries are crowned by the rudiments of an adherent perianth, seated within a coriaceous involucre of various figure, and with several cells and several ovules, most of which are abortive; ovules, twin or solitary, pendulous; stigmas, several, nearly sessile, and distinct; fruit, a bony or leathery nut, of one cell, and more or less enclosed in the involucre.

The following are the most familiar genera:—*Quercus*, of which *Q. pedunculata* and *sessiliflora* are the British oaks; *Q. suber*, the cork-tree; *Q. Ilex*, the evergreen oak; *Q. rubra*, the scarlet oak of America; and *Q. infectoria*, the gall-yielding oak. *Fagus*, of which *F. sylvatica* is the common beech of our woods; and *F. ferruginea* has edible fruit. *Castanea*, to which belong *C. vesca*, the edible sweet chestnut; and *C. pumila*, the dwarf Virginian chestnut. *Corylus*, of which *C. Avellana* is the common hazel-nut or filbert, which yields an oil used by artists and watchmakers. *Carpinus Betulus*, the humble hornbeam of our hedges; and *Ostrya vulgaris*, the hop hornbeam. The hornbeams are by some botanists ranked under the Birch tribe, on account of the involucre not forming so complete a cupule as the other genera; but this seems too minute a distinction, as the involucre is not more leafy than it is in some of the filberts. The members of the family abound in Europe, Asia, and North America, and generally in temperate regions, more sparingly in South America; they are altogether absent from the south of Africa.

The bark in all the species is bitter and astringent, and is used for dyeing, tanning, and for medical purposes. Their timber is in general employed as a durable material for house and ship building, and implement-making—as that of the oak, chestnut, and beech. In a few, the fruit is bitter and disagreeable; but in the majority it is farinaceous, and frequently contains an oily matter, used in domestic economy. Many of the lower animals derive their main subsistence from the acorns (beech-mast, chestnuts, and hazel-nuts) of this order; their fruit, as well as their bark and timber, is of the highest value to man. The gall-nut is an excrescence of the oak-leaf, caused by the puncture of an insect; it is used in medicine, and is the chief ingredient in ink and in black dyes.

Rafflesiaceæ.—Stemless and leafless parasites, the whole plant consisting of a single flower with a few scale-like bracts. Some plants of the order are of gigantic size, the flower of *Rafflesia Arnoldii*, a native of Sumatra, being capable of containing twelve pints of fluid in its cup, and attaining a weight of fourteen pounds. It grows on the roots and stems of vines (Cissus).

Coniferæ.—One of the most important, as it is one of the best defined, of the natural orders. Its members are trees or shrubs, with a symmetrically branched trunk abounding in resin, and are familiarly illustrated by the Scotch pine, the spruce and silver firs, the larch, the cedar, the araucaria, the arbor vitæ, the cypress, and the juniper. The ligneous tissue of their wood is marked with circular discs having a central punctation; their leaves are linear, needle-shaped, or lanceolate, entire at the margin. The characters afforded by the fructification are:—Flowers, unisexual; males in deciduous catkins, monandrous or monadelphous, each floret consisting of a single stamen, or of a few; females in cones, whose scales arise from the axil of membranous bracts supplying the place of ovaries; destitute of style or stigma; ovules, naked, in pairs on each scale, with large micropyles at their apices; fruit consisting of a cone formed of the hardened scales, which become enlarged and indurated, and occasionally of the bracts also; seed, with a hard crustaceous testa. In speaking of the Coniferæ, it has been not inaptly remarked that 'the flowers are quite different from what is generally understood by that name, being in fact nothing but

scales; those of the male containing the pollen in the body of the scale, and those of the female producing the ovules or incipient seeds at the base.'

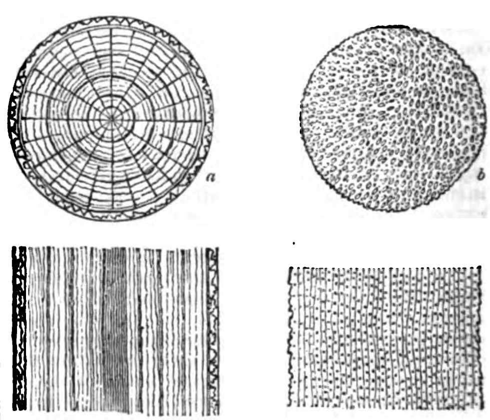
Well defined as the order obviously is, there are minor distinctions which warrant its subdivision into the following sections:—namely, ABIETINEÆ, the true pines and firs; and CUPRESSINEÆ, the cypresses. In the firs, the fruit is a cone, the scales of which open, and more or less recurve, when the seeds are ripe; the ovules are inverted; the pollen, oval, or curved: in the cypresses, the fruit is also a cone, but rounder, and with fewer scales, occasionally succulent, forming a galbulus; ovules, erect; pollen, spheroidal. In other respects—as in their foliage, habit, resinous secretions, &c.—they closely resemble each other. Of the Abietineæ the following are characteristic members:—*Pinus sylvestris*, the Scotch pine; *Abies excelsa*, the spruce fir; *Picea nobilis*, the silver fir; *Larix Europæa*, the common larch; *Cedrus Libani*, the cedar; and *Araucaria excelsa*, the Norfolk-Island pine—all of which are evergreens, with the exception of the larch. The Cupressineæ are well represented by *Cupressus sempervirens*, the evergreen cypress; *Thuja occidentalis*, the American arbor vitæ; *Taxodium distichum*, the deciduous cypress; *Juniperus communis*, the juniper of our moors; *J. sabina*, the savin-tree, as well as by the newer genera, *Saxe-Gothæa*, *Fitzroya*, &c.

The high importance of this order is derived from its timber, which in all is straight, easily worked, and durable. The *Wellingtonia gigantea* of California forms a lofty trunk ninety feet in circumference, and some other species recently introduced are not greatly inferior in point of size; but space would fail us to enumerate even the names of all the valuable additions that have of late years been made to this order, which is of so great national importance. Vast forests of pines occur in North America, which have yielded many species well adapted to our climate, such as *Abies Douglasii*, *Pattoniana*, *Pinus Balfouriana*, *M'Nabiana*, *Jeffreyi*, &c.; and indeed almost every gentleman's estate exhibits examples of this order, not only from America, but from almost every region in the world. The deodar and cedar, from the East; firs, cypresses, and junipers, from the far west; araucarias, from Chili and the antipodes; and cryptomerias, from Japan, form by far the most interesting, the most useful, and the most ornamental of our forest-trees, whether planted merely with a view to the raising of timber, or for the purpose of beautifying the landscape. (See ARBORICULTURE.) Many plants of the order are also valuable for their resinous productions; several kinds of pitch, tar, turpentine, gums, and balsams being procured from them. The large seeds of some are edible and wholesome; the succulent cones, or, as they are familiarly called, *berries* of the juniper are largely used in the preparation of gin; and the main ingredient in spruce-beer is an extract from several species of Abies. Great tanning powers exist in the bark of the larch; the savin, juniper, and others, possess stimulating and diuretic properties.

TAXACEÆ.—The yews are nearly related to coniferæ, and are usually associated with them. They differ in not producing true cones. The wood of many species is also peculiar, having spirals on the wood-cells as well as discs; but this we have recently ascertained to be also the case in some firs—such as *Abies Douglasii*, and an unknown kind of timber received from California in the form of a packing-box, which is perhaps the most beautiful of all woody tissues. The most highly prized timber of New Zealand is furnished by a plant of this order (*Podocarpus Totarra*); and species of *Dacrydium* are also valuable. In our own country, *Taxus baccata*, the yew, and many introduced species, yield excellent timber, and are also among the most ornamental evergreen trees and shrubs adapted to our climate. (See ARBORICULTURE.)

MONOCOTYLEDONOUS PLANTS.

The Monocotyledons or Endogens include those plants whose leaves have their veins placed parallel—as the palms, the grasses, the hyacinth and crocus, and whose stems have no distinction of pith, wood, bark, concentric circles, and medullary rays, like the Exogens (*a*), but consist merely of a confused mass of tissue (*b*). Their seed contains an embryo, having only one seed-lobe or cotyledon; hence the term Monocotyledon. Their trunks increase inwardly, instead of by external concentric layers; hence also the term Endogen. They are divided into three sections—DICTYOGENÆ, differing from all the others in having the leaves net-veined, and usually articulated with the stem; woody matter of the rhizome



Sections of Dicotyledonous and Monocotyledonous Stems.

disposed in wedges. FLORIDÆ, those having a perianth—such as the orchis, lily, palm, &c. GLUMIFERÆ, those which are destitute of a perianth, but have glumes or husks instead, like the grasses. The trees of this division are strictly tropical; the herbaceous species are found all over the globe.

§ 1. DICTYOGENÆ.

*Dioscoreaceæ—Yam order.
Smilaceæ—Sarsaparilla order.
*Trilliaceæ—Trillium order.
Roxburghiaceæ — Roxburghia order.
Philesiaceæ—Philesia order.

§ 2. PETALOIDEÆ.

*Hydrocharidaceæ—Frog-bits.
*Orchidaceæ—Orchids.
Apostasiaceæ—Apostasia order.
Burmanniaceæ—Burmannia order.
Zingiberaceæ—Ginger order.
Marantaceæ—Arrow-roots.
Musaceæ—Bananas.
*Iridaceæ—Iris order.
*Amaryllidaceæ — Amaryllis order.
Hypoxidaceæ—Hypoxids.
Hæmodoraceæ—Blood-roots.
Taccaceæ—Tacca order.
Bromeliaceæ—Pine Apples.
*Liliaceæ—Lilies.
*Melanthaceæ — Colchicum order.
Gilliesiaceæ—Gilliesia order.
Pontederiaceæ — Pontederia order.
Xyridaceæ—Xyris order.
Philydraceæ—Waterworts.
Commelynaceæ—Spider-worts.
Mayacaceæ—Mayaca order.
*Juncaceæ—Rushes.
Palmaceæ—Palms.
*Alismaceæ—Water-plantains.
*Juncaginaceæ—Arrow grasses.
*Butomaceæ — Flowering-rushes.
Pandanaceæ—Screw-pines.
*Typhaceæ—Bulrushes.
*Araceæ—Arum order.
*Orontiaceæ—Sweet Flags.
Pistiaceæ—Duck-weeds.
*Naiadaceæ—Pond-weeds.
Triuridaceæ—Triuris order.
*Restiaceæ—Restio order.
*Eriocaulonaceæ—Pipeworts.
Desvauxiaceæ—Bristleworts.

§ 3. GLUMIFERÆ.

*Cyperaceæ—Rushes.
*Gramineæ—Grasses.

DIOSCOREACEÆ.—These are twining, somewhat shrubby plants, with unisexual flowers in spikes, natives of the tropics, except *Tamus communis*, which represents the order in temperate climates. Various species of

Dioscorea yield edible tubers; and *D. Batatas*, recently introduced under the name of the Chinese Potato, is likely to prove a valuable addition to our garden esculents, although the hopes that have been held out of its supplanting the potato—now no longer a sure crop—may not be realised.

ORCHIDACEÆ.—This order consists of terrestrial or epiphytal herbaceous plants with enlarged roots and stems—the former in epiphytal species being clothed with an outer layer of spiral cells, which apparently serve the purpose of absorbing moisture from the atmosphere, and thus enabling the plant, which has no roots in the soil, to subsist and develop itself. The perianth consists of six segments in two rows, one differing in form from the rest, and called the labellum. The pollen-cells do not occur in the form of distinct grains, but are aggregated together in simple or compound *masses*, which become detached collectively. The flowers often imitate the forms of insects, as the bee orchis of Kent, and the more gaudy butterfly orchis of the tropics. The singular forms and intense colours of their flowers recommend these plants to the attention of horticulturists. Of the 3000 existing species, few are conspicuous for their uses. Species of *Eulophia* furnish salep; and the fragrant vanilla, used in confectionary and in the preparation of chocolate, is obtained from *Vanilla planifolia* and *aromatica*.

BROMELIACEÆ.—This family consists of about a dozen genera, and more than 170 species of plants, with scarcely any stem, and sometimes epiphytic in their habit. Their leaves are rigid, channeled, and often spiny or toothed at the margin. The perianth is tubular, its parts in two rows; the outer, or calyx, in three clefts, rigid, and persistent; the inner, petaloid and deciduous; stamens, six, inserted into the tube of the perianth; ovary, free or cohering, and three-celled; ovules, indefinite; style, single; stigma, three-parted, often twisted; fruit, capsular or succulent, three-celled, and many-seeded.

The principal genera are—*Bromelia*, the pine-apple; *Billbergia*, *Pitcairnia*, and the curious epiphyte *Tillandsia*, Spanish or Brazilian moss, or 'Tree-beard.' They are natives of moist warm climates—such as Brazil, West and East Indies; but many of them are cultivated in hothouses in Europe. All the above-named genera are common in our stoves and conservatories. The common pine-apple (*B. Ananas*) was named by Linnæus after Bromel, a Swedish botanist; and it receives its English name from the circumstance of its fruit being covered on all sides with small triangular scales, resembling the cone of a pine-tree.

The order has several important uses. The pine-apple, so much esteemed for its fine aromatic flavour, is perhaps the most delicious fruit in the world. What is called the fruit is, in fact, the fruits of the same spike cohering into one mass, by means of their succulent bracts. Several of the species are esteemed for their showy blossoms; the juice of others yields avinous liquor; and the tough leaf-fibres of many produce excellent cordage. Some of the Tillandsias, which hang their thread-like festoons from the trees of Brazil, are collected and used for stuffing mattresses, saddles, &c., making a pretty good substitute for horsehair. Most of the genera yield a fine aromatic odour; and from their habit of retaining water in the sheathing axes of their leaves, are said to be specially grateful to the traveller in the regions where they abound.

LILIACEÆ.—A very extensive, and to the florist one of the most important of the natural orders. Taking the common white lily as the type, there is a great resemblance in all the Lilyworts, not only in their habits and forms, but also in their essential characters; but botanists have somewhat perplexed themselves by subdivisions founded upon minute differences. It must be confessed that the limits of the order are not very clearly defined, and Lindley thinks it must ultimately be split up into several orders. The plants may be generally characterised as having usually scaly or tunicated bulbs; and leaves not articulated with the stem, either sessile or with a narrow petiole. In some of the genera, the flowers are erect and single, as in the tulip; in others, they are erect, but in umbels, as in the orange-lily; and in others they are in racemes and drooping, as in yucca; or single and drooping, as in the fritillary; or with the segments curved back, as in the martagon lily. Perianth, coloured, regular, and divided into six segments, occasionally tubular; stamens, six, inserted into the segments of the perianth; anthers, opening inwards; ovary, superior, three-celled, and many-seeded; style, one; stigma, simple or three-lobed; fruit, either a three-celled, three-valved capsule, or fleshy, and then occasionally tripartite. The seeds of the Asphodeleæ have a black, crustaceous, brittle testa; in the Tulipeæ and Hemerocallideæ the testa is brown and spongy.

Liliaceous.

The following plants may be mentioned as illustrative of the principal genera:—*Lilium candidum*, the white lily; *Tulipa sylvestris*, the wild tulip; *Allium cepa*, the onion; *Fritillaria Meleagris*, the fritillary; *Hyacinthus orientalis*, the garden hyacinth; *Agraphis nutans*, the harebell; *Asparagus officinalis*, the garden asparagus; *Muscari racemosa*, the grape hyacinth; *Erythronium dens-canis*, the dog's-tooth violet; *Phormium tenax*, the New Zealand flax; *Aloë*, the aloe; *Hemerocallis*, the day-lily; *Scilla*, squills; *Asphodelus*, king's spear—all of which are within the reach of every one's examination. The Lilyworts are found in every quarter of the globe, being more abundant, however, in temperate than in tropical climates, where they exist chiefly in arborescent forms.

The properties of the order, as may be expected, present considerable differences. All the Asphodeleæ contain a bitter stimulant principle and have a viscid juice, as is exemplified by the onion, garlic, leek, and chives. The roots of some are purgative, as the aloe; while those of several lilies are eaten in Siberia, as potatoes. Gum-dragon is the styptic juice of *Dracæna Draco*, a large tree; New Zealand flax is the tough fibre of the leaf of *Phormium tenax;* squills is a well-known demulcent; and the succulent suckers of asparagus are largely eaten as a vegetable. *Xanthorhœa hastile* and *arborea* are the grass-trees of New South Wales, which yield a resin used by the natives for fixing wooden handles to stone hatchets or hammers. Many of the species are cultivated solely for their fine showy flowers.

PALMACEÆ.—An important order of arborescent endogens, with lofty, usually unbranched trunks, bearing a tuft of leaves on the summit. The leaves are large, with a plaited vernation; flowers small, arranged on a simple or branched spadix, which is enclosed in a spathe bursting on the under side; florets, bisexual or polygamous; perianth, six-parted, and persistent, its parts in a double row—the three outer segments often smaller, the three inner sometimes deeply connate; stamens inserted into the base of the perianth, usually six, seldom three, and in a few polygamous species, indefinite; ovary, one or three celled; or deeply three-lobed; ovules, three, rarely one; fruit, baccate or

Palm.

drupaceous; albumen, cartilaginous, often ruminate, with a central cavity.

The principal genera are—*Cocos*, the coco-nut; *Phœnix*, the date-palm; *Sagus*, the sago-palm; *Calamus*, the common cane; *Areca*, the betel-nut; *Borassus*, the Palmyra-palm, yielding Palmyra-wood; *Ceroxylon*, the wax-palm; *Elais; Sabal;* and *Acrocomia*. They are strictly inhabitants of the tropics, to the natives of which they are undoubtedly the most useful order of vegetation.

The properties of the Palms are numerous and varied—wine, oil, wax, flour, sugar, salt, thread, utensils, habitations, and food, being obtained from numerous species. The coco-nut, sago, date, areca, betel-nuts, and palm-oil, are well-known products. *Coir*, which is worked into mats and cordage, is the dry fibrous pericarp of the coco-nut.

BUTOMACEÆ.—A small order of aquatic plants, having very cellular leaves, furnished with parallel veins, and handsome umbellate flowers of a purple or yellow colour. Calyx, three-sepaled, usually herbaceous; corolla, three-petaled and coloured; stamens, definite or indefinite; ovaries, superior, three, six, or more, either distinct or united; follicles, many-seeded; seeds, minute, attached to the whole inner surface of the fruit.

The genera are—*Butomus*, *Limnocharis*, and *Hydrochleis*, which abound respectively in the marshes of Europe, South America, and the East Indies. *B. umbellatus*, the flowering rush, is common in our ditches and by river-sides in some parts of Britain, growing from two to three feet high, with sword-shaped leaves, and umbels of rose or purplish white flowers. *Limnocharis Plumieri*, a native of Brazil, has yellow flowers, and the apex of each leaf is furnished with a curious pore, apparently for the discharge of the superabundant moisture which constantly distils from the plant. All the members are very pretty plants; the common flowering rush being universally acknowledged as one of our handsomest native aquatics.

Flowering Rush.

The order is said to possess acrid properties; and most of the species yield a milky juice. The rhizome and seeds of the flowering rush had once an officinal value.

CYPERACEÆ.—The plants in the section Glumiferæ of the Monocotyledons are destitute of a regular calyx and corolla, having instead green or brown scales to cover the stamens and pistil. The glume or chaff of the oat (see fig.), is a familiar example of this kind of envelope. The Sedges (CYPERACEÆ) and the Grasses (GRAMINEÆ) are the only orders ranking under this sub-class. We can merely glance at the latter—naming a few of the genera which lie within the inspection of every reader.

GRAMINEÆ.—One of the most important and valuable, as it is one of the most extensive, of the natural orders. According to the latest authorities, it comprehends 4000 known species, including the common grasses of our pastures, the bread-plants or cereals—wheat, barley, rye, oats, &c.—and the sugar-cane and rice. Their roots are fibrous or bulbous; their culms or stems cylindrical and hollow, except at the joints, where they become solid, the whole culm generally covered with a silicious coating; leaves alternate, and though sheathing the stem, not united round it; flowers in spikelets, and arranged in a spiked, racemed, or panicled manner. The characters of the fructification, according to Dr Lindley, are—flowers usually hermaphrodite, sometimes monœcious or polygamous, consisting of imbricated bracts, of which the most exterior are called *glumes*, the inferior immediately enclosing the stamens, *paleæ*, and the innermost at the base of the ovarium, *scales:* glumes, usually two, alternate, sometimes single, most commonly unequal; paleæ, two, alternate, the lower or exterior simple, the upper or interior supposed to be composed of two united by their contiguous margins, and usually with two keels; scales, two or three, sometimes wanting; stamens, hypogynous; anthers, feathery or hairy; pericarp, usually undistinguishable from the seed, membranous; albumen, farinaceous.

The Grasses are scattered all over the globe, and are the most directly useful of all vegetation both to man and to the lower animals. The following well-known plants may be taken as illustrative of the order:—*Triticum vulgare*, common wheat, which, according to the experiments of Fabre, appears to have originated from a small weedy grass (*Ægilops ovata*), not uncommon on the shores of the Mediterranean. *Hordeum distichum*, common two-rowed barley; *Secale cereale*, rye; *Avena sativa*, common oat; *Zea mays*, maize or Indian corn; *Saccharum officinarum*, the sugar-cane; *Oryza sativa*, rice; *Bambusa*, the bamboo; *Phleum pratense*, cat's-tail grass; *Agrostis stolonifera*, fiorin grass; *Anthoxanthum odoratum*, sweet-scented vernal grass; *Dactylis glomerata*, cock's-foot grass; *Festuca pratensis*, meadow fescue; *Lolium perenne*, rye-grass; *Briza media*, quaking grass; *Alopecurus pratensis*, meadow fox-tail grass; and *Holcus lanatus*, woolly soft grass. The cereal grains are plants of very ancient cultivation, and not being now found in a wild state, the origin of some of them is doubtful. Though allied in many respects to the Sedges, the Grasses are readily distinguished by their hollow-jointed stems, and leaves that sheathe, but do not completely surround, the stem like a tube.

Sugar-cane.

As food for man and beast, the value of this order is too well known to require more than a passing notice. Wheat, barley, oats, rye, rice, guinea-corn, millet, maize, and the sugar-cane belong to it, with the products of which every one is familiar. The straw or dried culms are used as fodder, litter, thatch, and as material for the manufacture of ladies' bonnets. All the Grasses—from the bamboo and sugar-cane to the common rye-grass—have a thin silicious coating on their stems, which seems intended to furnish them with greater strength and durability than could have been procured by simple ligneous fibre.

CRYPTOGAMS, OR ACROGENS (FLOWERLESS PLANTS).

This class of vegetation is readily distinguished by none of its members bearing proper flowers—hence the terms *Cryptogamia* and *Flowerless*. The higher forms exhibit a peculiar kind of tissue, called scalariform vessels, as well as spiral vessels; but the lower forms consist of cellular tissue only. They exhibit very different

degrees of organisation—the highest (*ferns*) having both stems and leaves, and the lowest consisting of simple-jointed threads, or even mere individual cells. Between these two extremes there are various conditions of stem and leaf—the two most frequently graduating into each other, and forming neither true leaf nor stem, but thin expansions, termed *thalli*. Cryptogamic plants do not originate from seeds, containing embryos, like the flowering-plants, but are reproduced by means of spores—bodies which in their simplest form consist of a single cell, but which are very varied in morphological character in different families.

§ 1. ACROGENÆ.

*Filices—Ferns. *Equisetaceæ—Horse-tails.
*Lycopodiaceæ—Club-mosses. *Bryaceæ—Mosses.
*Marsileaceæ—Pillworts. *Hepaticæ—Liverworts.

FILICES.—In this order the different parts of the plant spring from a *rhizome*, or root-stock; the elegant fronds or leaves being either separate and independent, or uniting by their stalks so as to form a sort of trunk, as in the tree-ferns. The fronds are furnished with forked veins, and are usually pinnatifid, and more or less compound; sometimes nearly simple and entire; in their vernation they are circinnate—that is, they unroll from the stem outwards in the form of a crozier. The reproductive organs appear on the mature plant in the form of *sori*, or brown membranous-looking spots, usually either upon the backs of the fronds, or on their margins. These sori either lie under a small shield-like *indusium*, or they are naked; or they are arranged along the margin of the leaf, which curls over them, and supplies the place of the indusium. Each sorus consists of a number of brownish bodies, called *thecæ*, each being in reality a case containing a number of minute *spores*, which are the true reproductive bodies. (For details of the development of these spores into plants, see VEGETABLE PHYSIOLOGY, page 75.)

The Ferns are divided into the following sub-orders:—1. POLYPODIACEÆ; sporangia in variously shaped sori on the back or margin of the frond, each having an elastic ring or rachis (vertical and incomplete, or horizontal and complete), by means of which the ripe sporangium is torn so as to set the contained spores free. 2. OSMUNDACEÆ; sporangia on a transformed contracted frond, with a terminal or dorsal ring more or less complete, reticulated, and opening vertically. 3. OPHIOGLOSSACEÆ; sporangia in spikes, sessile on a contracted frond, exannulate, two-valved (vernation of frond straight). 4. DANÆACEÆ; sporangia dorsal in masses, exannulate, splitting irregularly by a central cleft. The first sub-order is illustrated by the following genera:—*Polypodium*, the polypody, which has naked sori; *Lastrea*, the shield fern; *Cistopteris*, the bladder fern; *Asplenium*, spleen-wort; *Pteris*, the common brake; *Athyrium*, to which belongs the lady fern of our woods; *Adiantum*, maiden-hair; and *Scolopendrium*, hart's-tongue, the frond of which is tongue-shaped and simple. The second sub-order is represented by *Osmunda*, the flowering fern; *Anemidictyon*, and *Lygodium*, the climbing fern. The third sub-order contains *Botrychium*, the grape fern; and *Ophiglossum*, the adder's-tongue; and the fourth, a few exotic genera. The Filices are widely distributed, delighting in humid soil and shady situations—some growing on trees.

Tree Fern.

The fronds of the family generally contain an astringent mucilage, and are thus considered as pectoral; the roots of some have recently been used successfully as anthelmintics and purgatives; and *Aspidium fragrans* has been employed as a substitute for tea. The young leaves and rhizomes of some New Zealand species are edible; and the fronds of the common brake, when burned, yield a considerable quantity of alkali.

Lycopodium (Club-mosses), Equisetum (Horse-tails), and Rhizocarpeæ (Pepperworts), are usually classed as FERN ALLIES. They display considerable variety of structure, and will well repay careful study.

BRYACEÆ.—The Mosses present many points of interest, and are daily acquiring new admirers. They are minute plants, with erect stems and small leaves, all their tissues cellular. At certain seasons, little flower-like heads are produced, some containing antheridia (so named from their resemblance to anthers), and others less conspicuous, consisting of pistillidia, which represent the female parts. At maturity, each antheridium opens at the apex, and emits a granular gelatinous mass; this consists of minute spermatozoa, which find their way into, and impregnate the pistillidia, and thus give rise to the development of the latter into an urn-shaped theca or spore-case, containing spores capable of germinating into new plants. We have stated these phenomena without an expression of doubt, because, although the act of impregnation has not been, and cannot, in the nature of things, be directly observed, the theory accords with every known fact, and is as fully proved as the present state of knowledge will permit.

Mosses grow usually in shady situations, and are abundant in wet, cold countries. Species of *Sphagnum* form peat; otherwise, their uses are unimportant. They are divided into three sub-orders—SPHAGNEÆ, ANDRÆEÆ, and BRYEÆ. Of the first, *Sphagnum*, bog-moss, is the only genus; the second is illustrated by the split-moss (*Andræa petrophila*), which is common on the Scottish hills; while the third embraces the genera *Bryum* and *Hypnum*, and most other British mosses.

§ 2. THALLOGENÆ.

The orders under the Thallogenous sub-class of Cryptogams, are—

*Lichenes—Lichens. *Algæ—Seaweeds.
*Fungi—Mushrooms. *Characeæ—Stoneworts.

LICHENES.—Lichens form not the least interesting section of the Cryptogamia, and their value on the score of utility is by no means unimportant. They are familiar objects to all in the form of apparent discolorations and incrustations on old walls and rocks; but some of them hang in festoons from the branches of trees (*Usnea*, *Alectoria*), while others (*Peltidea*) spread their thalli among mosses and herbage in shaded situations. They grow slowly, and attain an extreme age. According to Dr Lindsay, some of those growing on the primitive rocks of our highest mountain-ranges are at least a thousand years old. 'The hoary Usneas, Ramalinas, and Physcias, like the gray beard of an old man, silently but eloquently proclaim time's ravages, and illustrate the constant succession of life upon death, growth upon decay, which is going on around us.' In their reproductive organs, they approach the Fungi, but are well distinguished by the presence in their tissue of gonidia containing chlorophyll, which are capable of originating new plants.

The Lichens yield valuable dyes. Orchil, a red dye, supposed to have supplied the purple of ancient Tyre, is produced by *Roccella tinctoria*, a Southern European species which was discovered in the west of Scotland by Dr Balfour in 1855. *Cladonia rangiferina* is the Reindeer Moss, an important forage-plant in Lapland. Species of *Gyrophora* (*Tripe de Roche*) are edible, and furnished Franklin and his companions with food for many weeks in the arctic regions. Elaborate details of the much neglected uses of these plants are given in Lindsay's *History of Lichens*.

FUNGI.—The Fungi, or Mushroom family, which are among the lowest forms of vegetation, are extremely diversified in their size, shape, colour, and consistence.

The common field-mushroom is one of the best-known, and may be cited as a type of the family; but the puff-ball, truffle, morel, as well as the mould on cheese and stale bread, the mildew on trees, the rust on corn, the substance called dry-rot, and many other minute appearances of a similar nature, are all fungi. In the field-mushroom (*Agaricus campestris*), the plant consists first of some filamentous filaments or spawn, which look like roots, then the stipe or stalk, surmounted by the pileus or cup. 'When the mushroom first appears, the stalk is covered by a thin membrane, called the veil, which unites the cup to the lower part; but as the mushroom grows, this veil is rent asunder, and it either entirely disappears, or only a small portion of it remains round the stalk, which is called the *annulus*, or ring. Under the cup are gills or lamellæ, which are of a dark reddish brown; and attached to these are the thecæ, containing the spores.' Many—as the moulds, &c.—are mere microscopic jointed filaments, or filaments surmounted by little ball-like receptacles which contain the sporules, or are mere spherical or filamentous cells, which increase with astonishing rapidity, each cell containing a number of undeveloped ones.

Among the more familiar genera are—*Agaricus*, the mushroom; *Tuber*, the truffle; *Morchella*, the morel; *Boletus*, the puff-ball; *Puccinia*, the mildew; *Clavaria*, the yellow meadow fungus; *Podisoma*, the jelly-looking masses often found on juniper and savin bushes; and *Tubercularia*, the small, red, pimple-like fungus found on rotten sticks and trunks of trees. The Fungi are scattered everywhere—springing from the ground, yet without roots; under the ground, as the truffle; on all decaying organic substances; and even on living animals, as the *Achlya prolifera*, which looks like a whitish slough or slime on gold-fishes, yet is a true rapidly developing fungus. Even what we call yeast is but a spherical-celled fungus, having a nucleated development.

The plants of this order are not more diversified in form than in properties. Some are wholesome and palatable—as the mushroom, morel, truffle, &c.; others, similar to these in appearance, are deadly poisons. Many of the minuter fungi—as moulds, smuts, rusts, &c.—are noxious to the human system. Ergot forms a powerful and dangerous medicine. German tinder is prepared from a species of boletus, which, after being dried, is impregnated with nitre. The Siberian fungus is used to induce intoxication.

The vinegar plant is one of the most singular forms of fungi; it is an abnormal state of *Penicillium glaucum* developed in saccharine fluid, which it has the property of converting into vinegar of a good quality, suited for table use. It consists of a gelatinous substance of a pale brownish colour. If placed in a jar containing a solution of sugar, or a mixture of sugar, treacle, and water, and allowed thus to remain for six or eight weeks in a kitchen cupboard, the solution will be found to have become converted into vinegar; this change being due to a kind of fermentation caused by the plant. The flocculent matters which form in stale vinegar—when it becomes 'mothery'—wine, saccharine solutions, ink, &c., appear to be of the same nature.

ALGÆ.—The Algæ form a highly interesting family of plants, and are specially important to the physiologist, for it is in these that the phenomena of growth and reproduction are most successfully studied. This order —which has been wisely split up into *several orders*, concerning which our space will not permit of full details— embraces the very simplest forms of vegetation, as well as many having a complicated structure. The Algæ are not confined to the sea; many occur in fresh water and on the dry land. They are classified as follows:— 1. FUCACEÆ; brown-coloured sea-weeds. 2. RHODOSPERMEÆ; rose-coloured sea-weeds. 3. CONFERVACEÆ; green-coloured sea and fresh-water weeds. 4. DIATOMACEÆ, Brittleworts; unicellular, in the form of frustules, usually coated with silica, and containing brown, rarely green, contents. 5. DESMIDEÆ; unicellular, without silica, containing always green cell-contents. The first contains many of our large species of common sea-weeds; the second, those beautiful kinds so highly prized for albums; the third, those green filamentous species so common in stagnant waters, some of which, as the Duddingston Cladophora, fill up lakes with their interlaced masses of filaments; the fourth, those minute silicious bodies found in such amazing quantities in all parts of the world, and which often descend in showers of rain; and the fifth, the analogous non-silicious species, which display perhaps the most beautifully symmetrical forms of the vegetable kingdom.

Such, according to our limits, is an outline of the Natural System of Botany; which, though as yet but partially developed, is infinitely more interesting and instructive than any artificial method, however elaborate and complete. Undeveloped as we must admit it to be, harsh and difficult as much of its nomenclature is, unnecessarily multiplied and complicated as its orders and tribes really have been, it has still the germs of truth and nature within it, and only requires a cordial and patient elaboration, on the simple principles of its great founder, to render it what it professes to be—an exposition of the system upon which Nature has proceeded in the creation of the Vegetable Kingdom. Our brief synopsis, as contained in this and the two preceding sheets, can at most but convey to the reader a very general notion of vegetable life and relationship, and only introduce him, as it were, to the technical phraseology and mode of procedure: for further acquaintance with the subject, we cannot refer to more accessible sources than the excellent works recently published by Professor Lindley of London, and Professor Balfour of Edinburgh. There the inquirer will find, in a connected form, all that is necessary to be known in ordinary cases; there, if he is ambitious of proceeding further, he will find references to trustworthy authorities, British and continental; and there, too, he may learn the best modes of practical investigation. To observe generally, to collect everywhere, to examine carefully, and to pronounce with caution, are the duties of the true phytologist; and the more attention to these, the sooner will the objects of a Natural System be accomplished. It is true that there are some difficulties at the outset—and where is the department of human knowledge without such obstructions?—but these overcome, and what a delightful field of intellectual enjoyment beyond! The beauty and variety of flowers, the fragrance and freshness which we are insensibly led to associate with them, have long been themes for the poet and moralist, but really not more so than the subject deserves. The endless forms in which plants appear, their adaptations to certain situations, the peculiar properties which many species possess, though all grow on the same soil, the wonderful metamorphoses which they undergo from seed to plant, and from plant and flower to seed again—not to speak of the amenity and beauty with which they invest the landscape, or of the utility they confer as articles of food, medicine, and clothing— are all subjects of never-failing interest to a cultivated mind. There is, perhaps, no pursuit which leads more directly to an appreciation of that wisdom and goodness which pervade creation, than the study of the vegetable kingdom, in which infinite variety, beauty, and elegance, singularity of structure, the nicest adaptations, and the most pre-eminent utility, meet us at every step, and compel us to observe and learn, even when often the least disposed to inquiry or reflection. Take it even in the light of a mere recreation for an idle moment, it is at least an innocent and cheerful one—one that never interferes with the comfort of a neighbour, or brings to the cultivator a single feeling of mortification or regret.

ANIMAL PHYSIOLOGY—THE HUMAN BODY.

THE general aspect of animals, and the characters by which they may be ordinarily distinguished from plants, have been already adverted to under VEGETABLE PHYSIOLOGY, and need not therefore be here enlarged upon. The chief structural differences which separate the two great sections of the organic world, are those which are connected with the mode in which food is assimilated—that is, converted into the materials of their respective fabrics. Thus it may be constantly noticed that plants imbibe their nourishment either through their external surface, or by prolongations of this into roots and leaves. On the other hand, all animals, except the very lowest in the scale of organisation, possess an internal cavity, the *stomach*, into which the food is received, and where it undergoes a preparation; and the absorption of it into the system takes place by vessels distributed on the walls of this cavity, or on a tubular prolongation of it, called an *intestine*. Plants require nothing but a regular supply of water, with carbonic acid, ammonia, and a small amount of saline or earthy matters dissolved in it; and the conditions of their growth generally afford them a constant supply of these, which they can imbibe by means of their roots and leaves, without moving from the place in which they are once fixed. But animals can only be supported by materials previously organised, all their food being derived from vegetable or animal substances, generally collected by themselves, and then reduced within their stomachs to a pulp, the nutritive portion of which is absorbed in a fluid state by the tissues, and the waste rejected by means provided for that end. On the whole, though the two lines or systems of life seem to start, as it were, from a common point at the base—the inferior forms bearing a certain similarity in structure and functions—yet this similarity quickly disappears as we ascend in the scale of development, and all the vital functions of animals are performed in a manner so different from those of plants, that no one can have the least difficulty in discriminating between them. Taking the human body as that whose external configuration is necessarily familiar to all, and that whose parts are most within the scope of examination, we shall endeavour, in the present treatise, to describe the structure and functions of its numerous organs, in language as popular as the subject will permit, and as concise at the same time as possible. Though chiefly directed to the human body, notice will be taken, under the several sections, of the analogous structure and functions in the lower animals, so as to convey to the reader an outline of Animal Physiology in general, and thus prepare him for a more intelligent perusal of the succeeding numbers on SYSTEMATIC ZOOLOGY.

Zoological science places the human being in the class *Mammalia*, or suck-giving animals, and in the order *Bimana*, comprising the two-handed creatures of that class. An erect posture is the peculiar characteristic of man, and it is one which gives to his aspect that dignity becoming his high place in creation. By the adaptation of an erect structure, also, his hands are left disengaged, and ready for the numerous operations to which he is inclined by his judgment or urged by his wants. His general stature is between five and six feet. A combination of hard and soft parts forms the material of his frame, the soft portions being arranged, generally speaking, upon and around the more solid parts of the structure. These latter parts consist of a beautiful framework of bones, termed the *skeleton*, which naturally occupies the first place in our description. *Muscles* and *tendons*, which are the organs of locomotion; the *brain* and *nervous system*, or organs of sense, feeling, and intellect; the *lungs*, for respiring the air essential to the maintenance of the principle of life; the *stomach* and *digestive organs*, for the supply of nourishment; the *heart*, *blood-vessels*, and *absorbents*, for the circulation of vital fluids through the body—these, and other important parts, will fall to be described after the solid framework on which they rest has received its due share of our attention.

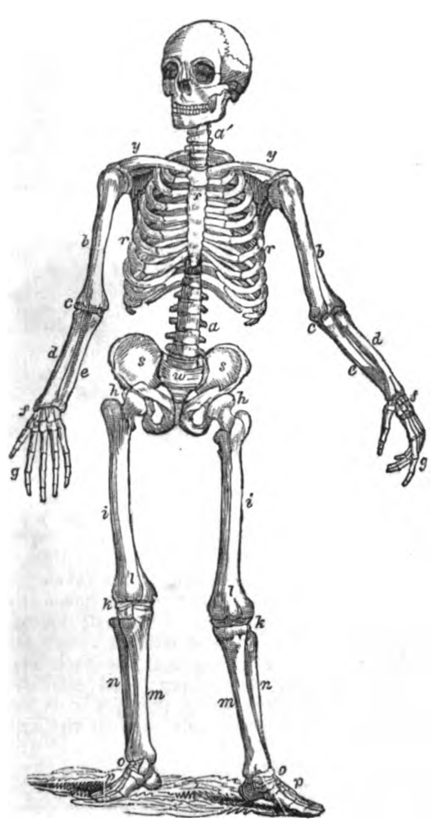
THE BONES.

The skeleton comprehends three main divisions—the head, trunk, and extremities—which consist, in all, of 254 bones, joined together in a manner combining great strength with ease and freedom of motion. The whole of the bones are composed of nearly the same materials—namely, earthy matter, chiefly lime, and gelatine or animal glue. According to Berzelius, 100 parts of human bones are composed of 51·04 phosphate of lime, 11·30 carbonate of lime, 2 fluoride of calcium, 1·20 soda and chloride of sodium, 1·16 phosphate of magnesia, and 33·30 animal matter, consisting of albumen, gelatine, and fat. This notable proportion of lime imparts to them the necessary hardness and solidity, while the animal matter cements or binds them together, and renders them not easily broken. Weighed *en masse*, a middle-sized adult skeleton ranges between 160 and 200 ounces, or from 10 to 13 pounds avoirdupois. Individually, the bones vary in solidity and weight, the heaviest in proportion to their size being those of the skull, the extremities, and the pelvis or under part of the trunk. The surface of human bone is for the most part smooth; and the interior, beneath a layer or coating of more condensed substance, is porous and spongy. The bones of the extremities in the dried condition—as ordinarily exhibited in our museums—are tubular, like pipes; but, strictly speaking, they are not hollow in the natural state, because the centre of the shaft is occupied by fatty matter, which in this situation is usually called the *marrow*. By this arrangement the bones are at once rendered light and strong; and compact as they are, they are nevertheless provided with blood-vessels, which indeed are essential to their vitality and growth.

The crown or summit of the osseous fabric is occupied by the cranium or skull, which is composed of eight bones—the *frontal*, the *occipital*, and the two *parietal*, constituting the greater part of the outward skull, before, behind, and laterally. The two *temporal* or temple-bones, on the under part of each side, and the *sphenoid* and *æthmoid* bones, placed at the base of the skull internally, are the remaining bones of the head. The union of these bones is remarkably firm and strong in the adult being. In some cases, the osseous plates are joined by serrated or ragged edges, like the teeth of a saw; in other instances, they overlap each other, like the ridge of a house—the arrangement in each case being precisely the one best fitted to insure strength and stability in the particular part. Altogether, an arch of the most powerful kind is formed, for the safe protection of the important organ within—the *brain*. The bones of the face, situated below and before the cranium, are numerous. Among the facial bones are reckoned the two upper *maxillary*, or jaw-bones; two *malar*, or cheek-bones; two *nasal*, or nose-bones; two small bones, attached to the nose internally, called the *turbinated* bones; two *palate* bones; the two *lachrymal* bones, situated in the orbit; the *vomer*, or ploughshare bone,

forming a part of the basis of the nose; and the single lower *maxillary*, or jaw-bone proper.

The bones of the skull and face rest upon the top of the spine or back-bone, which consists of twenty-four separate pieces, called *vertebræ*, firmly and curiously jointed the one into the other. The column of the spine is curved in several places, the most prominent being a curve forwards near the middle of the back. Seven of the vertebræ are called *cervical*, twelve *dorsal*, and five *lumbar*, from being situated respectively in the neck, back, and loins. Each vertebra has various projections and depressions, to admit of a firm union with those adjoining it; and by the junction of the whole, a long hollow or canal is made, for the reception of the spinal marrow. In the figure, the upper part of the



vertebral column is marked *a'*, and the lower *a*. The second of the vertebræ of the neck sends upwards a projecting pinion or tooth, which is received into a corresponding depression in the one above, thus forming the pivot upon which the head turns. A ligamentous band keeps the tooth-like projection of the second vertebra in the depression of the first; and nothing can better shew how completely our life, during every instant of its duration, depends on the maintenance of every single part, however minute, in order: if this ligament, scarcely thicker than strong paper, were to give way, instant death from pressure on the spinal marrow would ensue. The bones of the spine rest upon the framework of the *pelvis* (*s*, *s*), which is a hollow, basin-shaped cavity, formed by the approximation of two large bones, or *ossa innominata;* these constitute the lower part of the trunk, and give to it firmness and stability. The spine is fixed to the pelvis by means of the *sacrum* (*w*), a series of five imperfect vertebræ, consolidated into one piece in advanced life, which sink like a wedge between the pelvic bones of each side. The sacrum terminates in a loose osseous peak, called the *os coccygis;* this is in reality a compound bone, consisting of a chain of ossicles —three or four, and sometimes five in number—which are rudimentary vertebræ, and analogous to the more numerous tail-bones of the lower animals. The strong, hollowed innominate bones of the pelvis are marked by large round cup-like depressions on the outer and under surface of each, which form sockets for the two upper bones of the leg.

At the top of the spine, immediately below the vertebræ of the neck, are situated on each side the collar-bones, or *clavicles* (*y*, *y*), which are long and narrow in shape, and pass in a semicircle or arch from the front of the chest backwards, or, in other words, from the *sternum*, *x* (breast-bone), to the top of the shoulders. On the back of the ribs, at each side, lie the shoulder-blades, or *scapulæ*, which are thin flat bones, of a triangular shape. They rest loosely on the back, having scarcely any attachment, except by muscles, to any of the neighbouring bones. By this means they have a free and easy motion, and also communicate the same property in part to the arms, the upper bone of which is attached on each side to the scapula. A very small cavity in the latter bone admits the round ball-like head of the humerus, giving to it the most unconfined play of movement, whether of a rotatory kind, upward, downward, or sideways. Nothing can be more beautiful than the whole arrangements for permitting the arm to perform the multifarious motions which man requires from it. The *humerus*, a single bone in each arm (*b*, *b*), cylindrically shaped, is united at the elbow-joint (*c*, *c*) to the two bones of the forearm, termed the *radius* (*d*, *d*) and *ulna* (*e*, *e*). One of these, the ulna, is attached to the humerus by a hinge-joint—like that of a common door— while the radius is connected to the same bone by a round button-like head, which, being slightly concave, receives a projecting knob of the humerus, and admits of rotatory movements being performed by the lower part of the arm. These peculiarities of structure are essential to the free use of the hand. At the wrist, the position of the radius and ulna is in some measure reversed, the radius forming with the *carpal* bones (*f*, *f*) a joint like that of a door-hinge, while the ulna is in a measure left loose. The carpal or wrist-bones are eight in number. They are of small size, and lie in two rows, being jointed together in a manner that combines great strength with a certain degree of mobility. In the direction of the points of the fingers they are united with the *metacarpal* bones, forming the palm of the hand, and to which the *phalanges* (*g*, *g*), or finger-bones, are attached. Each finger has three bones in it; the thumb, or opposing finger, has only two.

As has been said, the bones of the pelvis, on each side, are marked by deep cup-like concavities, which receive the heads of the thigh-bones, *h*, *h*, *i*, *i* (*femur*), the upper bones of the lower extremities. As was required by the different nature of the purpose to be served, the ball-and-socket joint of the leg is much stronger than that of the arm, and permits of much less freedom of motion. The *femur*, or thigh-bone, is a rounded cylindrical bone, terminating at the knee in a connection with the *tibia* (*m*, *m*), the principal bone of the inferior part of the lower extremity. The knee-joint is a hinge one, but permits of a slight rotatory motion when the leg is bent. The tibia has a smaller bone, the *fibula* (*n*, *n*), placed by its side; and over the knee-joint is situated a small bone called the *patella* (*l*, *l*), or knee-pan, to which the principal muscles that move the joint are attached, and which serves to protect the parts against injury. The tibia and fibula form a union at the ankle (*o*, *o*) with the bones of the tarsus, which are seven in number, and constitute the heel or back part of the foot. These, again, are united to the *metatarsal* bones (*p*, *p*), forming the body of the foot, and five in number. To these again are joined the *phalanges* of the foot, fourteen in all, two

being attached to the great toe, and three to each of the others.

The *costæ*, or ribs (*r*, *r*), proceed from the vertebræ or back-bones, and are twelve in number on each side. They bend round in a circular manner from their point of union behind, and seven of them, called the *true ribs*, are joined directly by gristle or cartilage to the breast-bone, while the remaining five terminate anteriorly in a common cartilage, which unites with the sternum below. Altogether, the ribs form a large hollow space for the reception of the lungs, heart, and other organs, and protect them from injury. The ribs move in an easy joint formed with the back-bone, and, with the intercostal muscles, contract and expand, to suit the motions of the lungs.

These are the principal bones forming the skeleton of the human being. All animals have not this osseous framework; it is only found, and that in a modified degree, in a certain number of classes—namely, in quadrupeds, birds, reptiles, and some fishes; all of which, from the principal feature in their structure, are called *vertebrated* animals. Some of the other tribes of beings have their framework, corresponding in purpose to bones, on the outside of the body, in the form of a coat-of-mail. This is the case with shell-fish, with the crustacea, and with many insects that have a hard external covering. It is only in the skeletons of the higher vertebrata, however, that we find a real analogy to the framework of the human being. In such cases, not only are the bones of the same form and construction, but of the same number also; and where we do not find them of the same number separately, several will be discovered to have been atrophied at an early stage of existence as unnecessary to the functions of the full-grown animal, or compacted into one mass. Thus comparative anatomy detects in the foreleg of the horse, the wing of the eagle, and the paddle of the whale, the same amount of parts as are separately exhibited in the arm of man.

THE MUSCLES.

The soft fleshy substance of the body, which gives plumpness and form to the whole, is the muscular part or *muscles*. These are the instruments of motion. And when we consider the various positions which the body and its members assume, the agility and quickness with which the most intricate movements are made, the ceaseless play of the heart, the heaving of the lungs, and the singular rapidity of articulation and speech, we need not be surprised that these muscles, upon which all such movements depend, should be many in number, and be deemed agents of paramount importance in the animal economy.

The muscles are of a reddish-brown colour; they are composed of accumulated threads or fibres, arranged sometimes in layers, sometimes in a straight position, and sometimes obliquely. They are of an elastic nature, somewhat like a piece of India-rubber, and, at the impulse of the will, are lengthened and shortened alternately. A muscle is generally thick or swelled out in the middle; it gradually gets thinner towards the extremities, and in many instances passes at one or both ends into a *tendon*, or tough white substance, which is attached to a bone, and serves the same purpose as a rope or cord, to fix the muscle to the point from which it is intended to act. These tendons are most numerous about the joints, especially the larger joints, where they allow of free and unrestrained action, and yet occupy little space in situations where a large swelling muscle would have been inconvenient. About the larger joints—such as the knee, elbow, and shoulder—there are also numerous glands, which pour out an oily substance, which serves at once to lubricate the joints and facilitate the play of the tendons.

There are from four to five hundred muscles in the human body, all necessary for performing the various movements and operations of the complicated machine. On each side of the back-bone there are several layers of strong muscles, which are fixed by tendons to every projection of the numerous bones composing the spine. These muscles keep the trunk of the body erect, and also permit of the varied motions of the back. There are a multitude of small muscles about the face, head, and eyes, whose various action imparts that expression to the human countenance which indicates the prevailing feelings and passions of the individual. The tongue is also supplied by intricate muscular fibres, giving to it that amazing volubility of action by which the vast number of sounds composing language are expressed. Many are attached to the lower jaw; but two in particular, the temporal muscles, proceed upward through an arch formed by a projecting arm of the temple-bone, and are fixed to the tendons of the head. These two muscles are the most powerful in moving the jaws in the operation of chewing the food, and are very large in several animals of prey. Another flat muscle inside the cheek is called the *buccinator*, or trumpeter muscle; it is interesting to notice, as a result of its peculiar function, that this organ is especially developed in glass-blowers and individuals who play on wind-instruments. The chest is supplied with numerous muscles, which move the ribs upward and downward in the action of breathing. A large flat muscle, called the *diaphragm*, stretched across the trunk from side to side, and separating the hollow of the chest from that of the belly, also contributes mainly to the process of breathing. The arm and hand are rolled inward and outward by a set of muscles, which are placed on the outer and inner sides of the respective bones: thus the outside muscles act in a contrary manner to the inside, and reverse motions may be alternately performed. The muscles of the forearm are fixed to the scapula, or shoulder-blade, to the chest, and to the clavicle, at the upper end, and to the bone of the arm at the other. The fingers are moved by muscles situated in the forepart of the arm, and have long slender tendons by which they are attached. Two beautiful provisions of nature are here observed: at the wrist, a circular ring of tendinous substance binds down the long tendons, which would, in their various motions, otherwise start up from their places. This ring at once keeps them in place, and permits their free and unhampered play. The other provision is seen in the construction of the tendons of the fingers. There are two principal muscles which move the joints of the fingers, and two sets of tendons, which are inserted, the one into the middle bones of the finger, the other into the third row of bones, or the extremities of the finger. In order to preserve their free action, and to make them lie in the most convenient manner, there is a loop or slit in the shorter tendon, by which the other passes through to its insertion in the point of the finger. By this means, the longest and strongest muscle moves the extremities of the finger where the greatest power is wanted, without impeding the action of the other. The muscles which move the lower extremities are thicker and more powerful than those of the arms. Several large muscles, acting in opposition to each other, are situated around the thigh-joints, and move them. They are fixed, one end to the trunk of the body, some pretty far up, especially two, which are spread upon the front of the abdomen or belly, on each side of the spine, while the other ends are attached to the thigh-bone. Several thick muscles, also, are situated at the back of the trunk. Two large muscles compose the calf of the leg, and join to form the tendon of Achilles, which is fixed to the heel-bone; these muscles act powerfully in bending the ankle, and in supporting the body in walking. The foot and toes are moved by several long slender muscles situated in the leg, which have tendons attached to them, and terminating on the toes, exactly similar to those of the hand and fingers.

The pelvis and lower limbs of man differ greatly from those of all other animals, in their superior proportional

strength, and in the number and fulness of the muscles. This was necessary, as man has been evidently intended by nature for the erect position. In the monkey tribe, whose general form approaches nearest to that of man, the narrowness of the pelvis or hip-bones, and the smallness of the muscles of the lower extremities, clearly shew that they were not destined by nature for the erect attitude; in fact, all animals of this class are furnished with four *hands* or *paws*, the hinder pair exactly resembling those in front. When they attempt to walk on the hind extremities, they cannot put the sole to the ground, but press on it edgeways. By the nice balancing of the muscles, and the great force which they exert, man is enabled to stand erect, and to maintain a firm position, or move forward at pleasure, notwithstanding that the body diverges from the perpendicular line of the centre of gravity. The head is also balanced upon the neck by means of strong muscles, whose constant, though unobserved, exertion is necessary to maintain it in its position; for in young children, when the muscles are as yet weak, and in persons asleep, the head has an inclination to droop, and in the dead body it falls down on the shoulder or breast. The muscles of the neck, therefore, may be said to exercise a power in some degree involuntary, or not under the command of the will, as the majority of the muscles of the body are. But there are other muscles still more distinctly removed from under the guidance of the will. The heart is nothing else than a hollow muscle, which contracts and expands without the consciousness of the being; and, in like manner, the muscles which perform the act of respiration or breathing are not moved by the will.

This division of the muscles into two classes—*voluntary* and *involuntary*—shews, as perfectly as anything could do, the care with which our frame is constructed. Had those muscles on which respiration and the action of the heart depend been placed under the control of the will, their functions would have been liable to be impeded at every turn by circumstances. Now, these organs cannot cease to act for the most trifling interval without fatal consequences. The arrangement, therefore, which renders their operation involuntary, is one to be admired, as essential to life and comfort.

THE BLOOD—BLOOD-VESSELS.

The blood is the medium by which all the solid and fluid parts of the body are supplied with their due nourishment. In its composition, therefore, will be found the majority of the substances of which the body is composed. The blood consists of a solid coagulable matter, called *fibrin;* of a series of *red globules* which form the colouring matter; and of *serum*, or whey-like matter, consisting of albumen and salts, the latter being held in solution; it is this matter which imparts to the blood its necessary fluidity. The following chemical analysis shews, according to Lehmann, the relative proportion of constituents found in a *thousand parts* of blood:—

Water,		795·45
Fibrin,		2·025
Corpuscles	Hematin, including iron,	8·375
	Globulin and cell membrane,	141·110
Albumen,		39·420
Fatty matters,		2·015
Extractive matters,		3·270
Chlorine,		2·665
Sulphuric acid,		·090
Phosphoric acid,		·663
Potassium,		1·825
Sodium,		2·197
Oxygen,		·535
Phosphate of lime,		·212
Phosphate of magnesia,		·148
		1000·000

From the heart, the centre of the circulation, this highly complex fluid is conveyed through the body by vessels called *arteries*, and is brought back to the same part by *veins*. The purpose of its thus making the circuit of the whole body, is to supply the necessary materials for increasing the bulk and repairing the daily waste which takes place by perspiration and the perpetual operation of the numerous excretory organs. The blood is restored to its nutritious state by the *chyle*, a juice formed in the stomach and intestines from the digested food: this chyle reaches the heart by one of the large veins called the left subclavian; from the right side of the heart it goes along with the venous blood to the lungs, and there it is mixed with the oxygen, or vital portion of the atmospheric air, by which process it is converted into bright-red arterial blood. In short, there are two distinct circulations of the blood in the system. By the one, the blood is conveyed and distributed over all parts of the frame, imparting, at every pulsation of the heart from which it issues, new life and nourishment to the whole. After traversing the body, it returns to the heart, deprived of its nutritious properties, and changed in colour from a bright to a dark red. Here the second circulation, which is through the lungs, commences. The blood is poured from the right side of the heart, which has divisions for the purpose, into large vessels which carry it to the lungs, and spreading out into countless branches, penetrates and permeates their whole substance. Collected again by other vessels of equal number and extent, it is conducted by them to the left side of the heart, to be propelled anew through the frame, restored to its bright-red hue, and repossessed of all its vivifying qualities. Both these changes are effected in the lungs. The *chyle*, which may be called the essence of our food in a liquid state, is conveyed from the stomach and intestines through the chest by a duct, which empties itself into one of the veins, immediately before the blood is transmitted through the lungs. It is in these organs that the chyle is thoroughly mixed up with the circulation; and it should be remembered that this chyle is the only benefit, the only real food, extracted from all the substances received into the stomach, the remainder being entirely useless and excrementitious. From the chyle comes the material of the bones, of the fleshy or muscular parts, of the brain and nervous cords, of the hair, nails, enamel of the teeth, and, in short, of every different structure of the system. The average quantity of blood contained in an ordinary-sized person is calculated at about thirty pounds' weight. The coloured globules of blood do not enter into the smallest vessels of the body, but only the thinner part of it, which has no colour; thus in the eye there are numerous blood-vessels, but these are so minute as not to admit the red parts of the blood; and this is a necessary provision of nature, in order that these organs may retain their pure transparency for the purpose of vision. In inflammation of the eyes, when these vessels are much enlarged, the red globules sometimes enter, and the eyes are then said to be bloodshot. What is called the *pulse* is the flow of the blood through the arteries, which is caused partly by the impulse of the heart's contractions or beatings, and partly by the contractions of the coats of the arteries. The rate of pulsation in a person in the prime of life is from sixty-five to seventy-five beats in a minute. In childhood, the pulse is much quicker—from 100 to 140 beats; and in old age, it again becomes slower than the medium standard. In fevers, inflammations, and other diseases of excitement, the action of the heart is increased sometimes to from 100 to 140 pulsations in a minute.

Blood-vessels consist of the heart, with its arteries and veins, which branch out through every part of the body, and carry the blood, by a constant circulation, through them. The heart is placed in the left side of the chest, a cavity divided into two parts by a thin membrane running perpendicularly down the centre, and supported below by the diaphragm. It is of a

round or conical shape, with the base or broad part uppermost, and the point slanting downwards and towards the front surface of the chest. It is of a thick muscular substance, with hollow cavities inside, and numerous cords or pillars of fleshy or tendinous substance stretching through these to give them support. In man, and all the higher animals that breathe air through the lungs, it is double, or has two distinct sides, each performing separate offices. In fishes, again, the heart is single; in insects, there is no proper heart, but a vessel that runs along the back, somewhat like an artery, through which the fluid corresponding to blood circulates through their bodies; other animals, still more simple in structure, have no trace of heart or blood-vessels. For these ends, the heart in man has two sides, a right and a left; and each of these sides contains two hollow cavities—the one called an *auricle*, from its fancied resemblance to the ear; the other, a *ventricle*, or belly. The manner in which the circulation of the blood is effected may thus be described in detail:—Two large veins—one from the upper part of the body, the other from the lower—enter the right auricle of the heart, and carry the blood, which has made the round of the body, into this cavity. Here it is of a dark-purple colour, and it is called venous blood, from its coming from the veins. From the right auricle it is sent, by a sudden contraction or forcing together of the two sides of the cavity, into the right ventricle, immediately below the auricle, and communicating with this by a small opening furnished with a valve; by the right ventricle contracting, it is conveyed by the pulmonary arteries into the lungs—the two large cell-formed substances on each side of the chest surrounding the heart. After passing through the lungs, it is returned by the pulmonary veins to the left auricle of the heart; from this it is sent into the adjoining left ventricle; and by a powerful contraction of this muscular cavity, it flows out by the great artery of the heart, the carotid, which distributes it through every part of the body, again to be returned by the veins: and thus the round of circulation is continually going on.

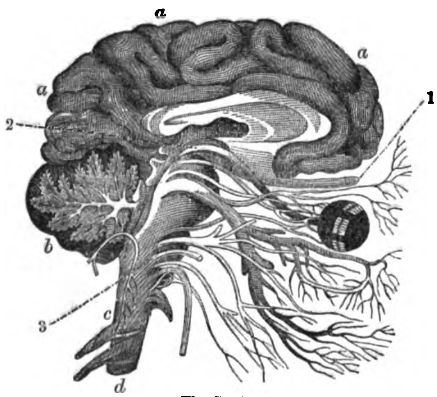
The heart being an extremely thick muscle, the force with which it contracts is very considerable. The left ventricle of the heart, too, although somewhat smaller, is much thicker and more muscular than the right, it having to send the blood through the whole of the body. A beautiful provision is observable in the heart, to prevent the flowing back of the blood into its different cavities during their alternate pulsations. In the passage of communication between the left auricle and ventricle are placed valves, which, when the ventricle contracts, to send the blood through the aorta, close accurately, so as to prevent a reflowing into the auricle. There is the same provision between the right auricle and ventricle, and also at the mouth or commencement of the aorta and pulmonary arteries, and the veins which communicate with the right auricle. Some of these valves are of beautiful structure; they are composed of three flaps that join accurately over each other; and to prevent their being pushed by the impetus of the blood beyond their proper position, they have little tendinous cords attached, of exactly the length required. In the child before birth, as it cannot breathe, and therefore the lungs are not used, there is a small hole or communication between the right and left auricles, by which the blood from the veins flows directly through to the arteries, and thus avoids going to the lungs: this hole is usually closed when the child begins to respire. The aorta, or great artery of the body, after it leaves the heart, passes upward in the form of an arch, when it gives off the carotid branches to supply the brain, and face, and arteries to the arms and chest. It then bends downward, and gives off branches to the stomach and other viscera; and when it comes to the lower part of the belly, it divides into two main parts, which become the arteries of the pelvis, thighs, and legs. The arteries of the body are composed of three coats or coverings, the principal one being a thick muscular ring, which encircles the artery, and which contracts and expands so as to assist in sending the blood onwards. The principal trunks of the arteries lie deep in the fleshy parts of the body; but their ramifications are so numerous and minute, that they pervade every particle of the human structure—bones, gristle, and every other texture. These extreme branches of the arteries are very minute, and previous to the employment of the microscope as an instrument of anatomical investigation, the nature of the connection between the terminal twigs of the arteries and veins was only a matter of conjecture. Now, we know that there is a third set of vessels interposed, called the intermediary or capillary system; they are exceedingly numerous, and anastomose freely with one another, their diameter in the human body seldom exceeding the $\frac{1}{3500}$th part of an inch. In the economy of growth and decay—or that continual building up and pulling down which is always going on in the animal frame—these structures are of the utmost importance, for it is by their means that the great functions of secretion, nutrition, and respiration are mainly brought about. By the aid of the microscope, the circulation of the blood, and other phenomena connected with the above-named functions, can be readily witnessed with the eye—these changes being studied in the transparent parts of animals, such, for example, as the web of a frog's foot, the tail of a fish or tadpole, and the wing of a bat. The veins are another system of vessels, which return the blood from the extremities of the body to the heart. They are larger and more flaccid than the arteries, and are distinguished from them by having no pulsation. A large vein generally accompanies the corresponding artery, but the great proportion of the veins lie more towards the surface, and are easily distinguished, swelling out under the skin. The numerous veins from the lower extremities join into one trunk in the belly, which vein, after passing through the liver, as will be afterwards described, joins the right auricle of the heart, the blood from the upper half of the body joining also by another similar vein. In the veins of the extremities that hang downward, and are apt to be gorged with blood, there are inserted numerous valves at short distances, which prevent reflux of any kind.

THE BRAIN—NERVES AND NERVOUS INFLUENCE.

The brain, as already mentioned, is contained in the cranium. It is a soft mass of matter, enclosed in certain protecting membranes beneath the bones of the skull. As the organ by which mind acts, and chief seat of the nervous energy, the brain may be described as the most important and dignified of man's bodily parts, and well deserves the most careful investigation. The brain is divided by strong membranes into two main sections—the *cerebrum*, or proper brain, which lies in front beneath the brow and on the top and sides of the head; and the *cerebellum*, or lesser brain, which lies behind. Both are longitudinally divided into halves or hemispheres, and also into lesser parts called lobes. The figure in next page offers a lateral representation of the different parts of the brain, as it lies beneath the skull, with its beautiful and minute radiation of nerves proceeding to the eye and other external instruments of the organs of sense.

The cerebrum or principal part of the brain is indicated by the letters *a*, *a*, *a*. The cerebellum, distinguished by the letter *b*, terminates below in the *medulla oblongata*, *c*, the cylindrical pulpy cord by which a union is formed between the brain and *spinal marrow*, *d*. The latter part is the long cord of soft matter formerly mentioned as lying in the canal formed by the range of the spinal bones. It is round, of the thickness of the finger, of the same kind of substance

as the brain, and formed of smaller nervous cords, running parallel to each other: it runs along the whole length of the back down to the pelvis. The



The Brain.

nerves are small whitish-looking cords, which proceed from the brain and spinal marrow, and spread out in innumerable branches to every part of the body. A large branch of a nerve generally accompanies every large artery, and every important part of the body has a branch of a nerve sent off to it. The nerves for supplying the organs of smell (1), of seeing (2), of hearing (3), together with the great sympathetic nerves, which give branches to the heart, lungs, stomach, and other important viscera, proceed directly from the brain. The nerves of motion and sensation, sent to the various parts of the trunk and extremities, take their origin, with a few exceptions, from the spinal cord. Two sets of nervous branches proceed from the cord on each side, corresponding nearly to the junction of every vertebral bone; and it is found that a branch of these nerves imparts motion, and the other sensation or feeling. The brain has a covering of three thin membranes; the outward one strong and thick, the inner, extremely thin and delicate. The nerves, which are soft and pulpy inside, have also a thin external covering which protects them. The nervous branches are never seen or felt in the living body, and what are vulgarly called nerves are the tendons of the muscles, the erroneous title being given chiefly to those about the wrists, fingers, and ankle-joints. Their great numbers and minute divisions are manifest, however, because we cannot prick any part of the body with the sharp point of a needle without wounding some of them, and thereby causing the sensation of pain. When the nerves are injured in their powers by disease, the sense of feeling in the part is entirely lost. The brain in the lower animals is not generally nearly so large, in proportion to their bulk, as in man; and the cerebrum, or upper brain, is often smaller in them than the cerebellum, or lower brain. In several classes of the inferior animals there is no distinct brain, but only nerves running along their bodies, and joining into knots or ganglia. The nervous system of insects and worms is of this description. In the *polypifera*, and many other lowly organised animals, a nervous system cannot be traced.

It may be proper here to make some observations on the functions of the brain, considered abstractly from its anatomy. Man surpasses all other animals in the height and proportions of the forehead, and in the comparative mass of brain in the upper part of the skull. In the human head, the lower parts of the face bear a smaller proportion to the forehead than in the brutes. The face is placed in nearly a perpendicular line with the forehead, instead of projecting outwards into a snout, as in the lower animals. The brute face is merely suited for the purpose of animal wants and for defence; the jaws are long and narrow, supplied with thick, strong muscles, and short teeth; there is not the elevated nose, which in man forms a distinguishing feature—the arched eyebrows—the exquisitely formed lips, and the rounded chin; above all, there is not that play of varied expression, that air of intelligence, and that indescribable emanation of a rational mind, that ray of divinity, at the appearance of which the most wild and ferocious of the brute creation are awed and subdued. But, besides, the Creator seems to have allotted characteristic external signs to express the passions of the mind, that in social life man might not easily impose on his fellow-man; for the various muscles of the face express the several passions of the mind so faithfully, that they may be even represented in painting. This is said to be the natural expression, and would appear to be understood even by animals; for a dog, on looking to the countenance of his master, easily recognises the mute expressions either of commendation or dissatisfaction. From the action of these muscles being so often repeated, *physiognomy* arises: the action of the prevailing muscles fixes an enduring expression on the features; and thus traces of frequent anger often remain in the countenance after the passion itself is gone off. With the power of speech and reason, man has also the means of expressing his feelings and passions by laughter and weeping, manifestations which are not found in the lower animals. Weeping proceeds from a deep emotion of the mind, and seems an effort of nature to relieve the system of grief. It usually begins with deep inspirations of the lungs, after which follow short alternate inspirations and expirations, and it is finished with a deep long-drawn expiration, which is immediately followed by an inspiration. When moderate, it certainly relieves the distress arising from grief. Laughter has its rise from some ludicrous ideas impressed upon the mind, and would seem to arise directly from a sort of titillation conveyed to the branches of certain internal nerves, probably those of the diaphragm; immediately to this succeeds a number of imperfect inspirations and expirations, which seem to be checked by the contraction of the glottis in the throat or larynx. Laughter, in a moderate degree, may be conducive to health, as it gives impulse to, and ultimately promotes, the circulation; carried to excess, however, it may prove dangerous, from accumulating too much blood in the lungs. Sneezing consists of one deep inspiration, succeeded by a powerful single expiration, and seems to consist of a convulsive effort of the muscles of breathing to throw off some cause of irritation in the sensitive membrane of the nostrils. The common hiccup is a spasmodic action of the muscles of the stomach, caused by something irritating the stomach itself. Some of the causes by which our mental happiness is either increased or diminished, proceed entirely from the bodily sensations. Any gentle stimulus applied to a nerve seems to cause a feeling of pleasure; strong stimuli, or any causes disturbing seriously the natural condition, produce pain. Itching is akin to pleasure, and in both cases the flow of blood is increased into the part in which either pleasure or titillation is perceived; but when further increased, it degenerates into pain or excessive sensations in the nerves. Anger violently excites the motion of the spirits, increases the motion of the heart, the frequency of the pulse, and the strength of the muscles; forces the blood into the extreme vessels; and even sometimes bursts the smaller vessels themselves; passion also increases the secretion of bile. Grief weakens the strength of the nerves and action of the heart, retards the pulse, destroys the appetite, and frequently produces paleness, looseness of the bowels, indigestion, and those slow or lingering diseases that take their rise from an interruption of the secreting glands, and a disease of their structure. Fear diminishes the force of the heart, weakens the muscular motions, relaxes the whole system, and, if

long continued, causes a general sinking of the body. Excessive terror often increases for the moment the muscular strength, even to convulsions; excites the pulse, interrupts the course of the blood, and in not a few instances has produced sudden death. Love, hope, and joy promote all the salutary actions of the body, gently quicken the pulse, promote circulation, increase the appetite, and aid the cure of diseases. Excessive and sudden transports of joy, however, often prove fatal, by increasing the motion of the blood, and exciting a fit of apoplexy. Shame, in a peculiar manner, retains the blood in the face, as if the veins were obstructed; when felt in an extreme degree, it has also been known to prove the cause of sudden death.

THE LUNGS OR BREATHING APPARATUS.

In the highest part of the cavity of the chest, on each side of the breast-bone, the lungs are situated. A membrane passing from the breast-bone to the back divides them into two portions—the right lung and the left lung. The right lung consists of three sections, called *lobes*—the upper, middle, and lower; the left lung, rendered smaller in bulk by the presence of the heart in the same cavity, has only an upper and a lower lobe. The lungs have a dark-bluish appearance, a familiar example of which is afforded in the *lights* of sheep—that part generally appended to the heart and windpipe. Inside they are composed of an immense number of cells, which alternately inflate or collapse as the lungs are filled and emptied of air. When an inspiration is made, and the lungs are filled with air, these cells become expanded; and the blood sent from the right side of the heart, and spread over the cells, is exposed through an extremely thin membrane to the air. An important change, as formerly alluded to, here takes place on the blood: from being of a dark-purple colour, it immediately changes to a bright scarlet, having absorbed or taken up all the oxygen, or vital part of the air, and parted with a corresponding volume of carbonic acid gas or fixed air, which it had acquired in its circuit through the vessels of the body. So essential is the matter imparted by the air to the blood for sustaining animal existence, that the breathing cannot be suspended even for a very short period without extinguishing life. It is probable, too, that the heat of the body is generated, and constantly kept up, in some way or other, by means of this process of breathing, and the change which the blood undergoes. We know at least that the evolution of carbonic acid cannot go on, in ordinary chemical processes, without an accompanying discharge of heat; hence it is presumed that the vital warmth, derived by the body from the blood, may be in this way produced. The lungs, like every other internal organ, are covered with a thin transparent membrane called the *pleura:* this membrane, as well as the substance of the lungs themselves, is liable to inflammation; and hence the name of the disease called pleurisy. The *trachea*, or windpipe, the communication between the mouth and lungs, is a hollow tube, having a series of cartilaginous rings passing round it, to prevent the possibility of its being compressed either by external means, or from the food in the act of swallowing, and, in consequence, the breathing obstructed. It takes its rise from the bottom of the mouth, and passes down in front of the neck, where its strong cartilage may be seen and felt. At its lower part, it divides into two branches, one going to join the right section of the lungs, the other the left.

Lungs for the breathing of air are only found in the higher classes of animals. Fishes are furnished with gills, those comb-like substances which lie within a flap on each side of the head; over them a stream of water is constantly sent by inhaling it at the mouth in a similar manner to breathing. The air, which is always present in considerable quantities in water, is thus absorbed by the blood-vessels while ramifying over the gills, and all the purposes of breathing are answered. In insects there are no lungs, nor do they breathe by the mouth, but along the sides of their bodies, by means of numerous holes with small tubes or spiracles, leading to a longer middle tube, by which the air enters and mixes with their fluids. When we descend lower in the animal scale, even this substitute for breathing ceases, the skin or general envelope of the body being sufficiently delicate to bring the circulating fluid in contact with the air, and thereby subserve the respiratory function.

THE TEETH—DIGESTING APPARATUS.

The first process performed in connection with the supply of nourishment to the body is that of masticating the food, and this is the office of the teeth.

The teeth are placed in the upper and lower jaw, to which they are attached by roots, which sink into the porous sockets of the jaw, somewhat in the same manner as a nail is fixed in a piece of wood, though they are retained in their place chiefly by the softer parts around. The teeth are composed of bony matter, covered externally with a thin coat of an extremely hard substance, called *enamel*. The teeth are furnished with nerves and blood-vessels, and have thus vitality like the rest of the body, although possessing it in a less perfect degree than most other parts of the structure. Hence they are very liable to disease and decay. In decaying teeth, a blackish spot is first perceived upon the outer crust or enamel; this substance gradually gives way, and then the bone below proceeds to rapid decay. The irritation of the air, and particles of the food, inflame the nerves and soft pulpy parts inside, and thus the excruciating pain of toothache is produced. The first set, or temporary teeth, begin to make their appearance in the child about the fifth or sixth month; and towards the end of the eighteenth month, the whole set of temporary teeth, consisting of twenty, have generally cut through the gums. These teeth continue till about the sixth or seventh year, from which time, till about the twelfth or thirteenth year, they gradually fall out one by one, and are succeeded by the second or permanent teeth. The roots of the temporary teeth are much smaller, and sink less deep into the jaw than their successors. The rudiments of the second set of teeth begin to form early in cavities below the others, and, gradually growing and pressing upward, displace them. The number of the permanent teeth is thirty-two, consisting of sixteen in each jaw. The four front teeth are called the *incisors*, and have one long root; on each side next to these is one eye or *dog* tooth; then there are placed two small *grinders* on each side, having double roots, and three large grinders, or molar teeth. The last of these is called the wisdom-tooth, from its making its appearance latest in the jaw, from the seventeenth to the twentieth year, or even later. By this change and gradual succession of teeth, we have a beautiful provision of nature for permitting the jaws to increase in size, and at the same time for preserving the relative positions and regularity of the different teeth; for had the first teeth of childhood been permanent, it is impossible that the jaw could have increased in growth without deranging the order and position of the whole.

The teeth of animals differ according to the kind of food on which they live. In the carnivora, or flesh-feeders, the teeth are sharp-pointed, and adapted for tearing their prey to pieces; in the graminivora, or those that live on grasses and other herbage, the teeth are of a rounded form, with broad surfaces, and the grinders are furnished with several layers of the hard enamel, following each other in succession, with a slight layer of common bone interposed; so that when the grinder is worn down by the friction of chewing, it is not rendered useless, but a new layer of the enamel is presented at the worn-down surface. Some animals—as the hare, rabbit, beaver, and mouse—have the front

teeth of a chisel shape, with enamel only on the outer side of them. These animals are called gnawers, because they chew or gnaw down their food in this particular manner; and by the inner soft part of the tooth being liable to be worn down, while the outer is harder, the enamel is thus always kept with a sharp edge. Some animals have large projecting tusks for defence—as the elephant, wild-boar, &c.; others—as fishes—are provided with teeth more for holding fast their prey than for mastication. Many have no proper teeth at all—as birds, worms, and other soft-formed animals. Man is characterised by having all his teeth set close to each other in a half-circle; they are of a medium form, between that of carnivorous and herbivorous animals; the front teeth are adapted for cutting; the canine are sharp, though not of undue length, and the grinders are suited for masticating vegetable and farinaceous matters—as nuts, &c. In short, the form of the teeth of man evidently points out that he is adapted to live on a mixed kind of diet, or a conjunction of vegetable and animal substances.

Stomach.—Behind the windpipe, taking its rise also from the bottom of the mouth, lies the *esophagus*, or tube which passes into the stomach. This tube expands at the top into what is called the *pharynx*, forming the whole of the upper part of the throat immediately behind the tongue. Into this cavity the windpipe opens, and to guard against any particle of the food or drink passing into the windpipe, instead of into the passage to the stomach, there is a little tongue or valve which closes accurately over the mouth of the windpipe every time food or drink is swallowed. When the substances have passed, the valve again springs open, and admits of free breathing. To shew how accurately and precisely every part of the human machine performs its duties, a celebrated writer has instanced this same valve, which, in a multitude of persons dining together, not one time out of a hundred in any one individual instance is at fault. When a drop of fluid or particle of food does by chance insinuate itself into the windpipe, so sensitive is this tube, that a convulsive cough is excited till it is again expelled. There is another little tongue or flap attached to the roof of the palate, and seen above the tongue when the mouth is opened. This, which guards the passage to the nose, is not, however, to be confounded with the other, which is further down the throat, and invisible. The esophagus, or gullet, passes down through the chest, traverses a ring in the diaphragm—that large muscle which stretches across the lower ribs, and which assists so materially in breathing. Immediately below this muscle, on the left side, is situated the stomach, which is partly sustained in its place by being attached to the esophagus, or tube from the mouth. The stomach is an oval bag of considerable size, occupying a slanting position immediately below the heart, with its right side overlapped by the left edge of the liver, and extending to the lower end of the breast-bone. The stomach has three coats—an external membranous one, a muscular, and a soft villous inner covering. The upper passage, by which this bag communicates with the esophagus, is called the *cardiac* opening; the lower, where the first gut commences, is called the *pyloric* orifice.

Digestion.—One of the most important operations in the animal economy is that of digestion, whereby the various substances used for food are dissolved in the stomach, and undergo changes, by which they are formed into matter fit for entering into the composition of the different parts of the body, to nourish its growth, and supply the daily waste which takes place in the system; for such is the constitution of animal bodies, that the substances of which they are composed are liable to constant waste; the solid parts are worn down, and a large quantity of fluid is constantly given off by the exhalent vessels, both from the skin and the surface of the lungs. This is manifest in the sweat and the vapoury exhalations constantly passing off by the mouth; and there is also an imperceptible perspiration regularly proceeding from the surface of the body, which has been computed to amount to several pounds in the course of a day. It must be evident, therefore, that if this waste was allowed to proceed but for a very short period, the body would soon be reduced to a state of complete decay. A constant supply of new material is therefore daily needed, to replace that which is wasted; and thus it has been supposed that a human body changes its whole materials many hundred times from the period of its birth till death; and that an individual, as regards his mere corporeal structure, is not at all the same at the period of manhood to what he was when a boy, nor in old age what he was in his prime. Although this change, then, is complete, even to the bones and most solid parts of the frame, it is brought about so gradually, and with the regular and minute substitution of one particle for another, that it is never perceptible. Man has been called, with relation to his diet, omnivorous, from his being adapted to live on every kind of food, whereas most other animals are confined to one particular description. The carnivorous animals live on flesh alone, the graminivorous on grass and green herbs, and the granivorous on grains and other smaller seeds. These animals never change their respective diets; nor, from the construction of their teeth, stomachs, and intestines, were they ever intended to do so. But in man it is plainly evident, from his anatomical structure, that he was intended to feed on every sort of food promiscuously, or that he could adapt himself to either animal or vegetable fare as habit or necessity impelled him. Man also differs from brutes in resorting to the arts of cooking, whereby the food is put into a state more fitted for digestion, and for yielding a sufficiency of nutritious aliment. The food being received into the mouth, is broken down and masticated by the teeth. It is here also reduced into a soft pulp by the saliva, which flows into the mouth by the salivary glands; and thus being sufficiently broken down and softened, it passes into the stomach. The stomach has numerous glands situated on its inner coat or surface, which secrete a peculiar fluid called the *gastric juice*, which is clear and colourless, with little taste or smell, or sensible qualities. On this fluid depends the important office of digestion. It has the power of coagulating substances in the stomach, of preventing the contents of the stomach from passing into a state of fermentation or putrefaction, and of dissolving the whole into one homogeneous mass. When the stomach is first filled with food, it appears to remain there for a short period without undergoing any change; gradually, however, successive portions of the food, as they come into contact with the gastric fluid, are dissolved; till at length, in a shorter or longer period, the whole is collected into a thin grayish paste, called *chyme*. The chyme, as it is gradually formed, moves to the other extremity of the stomach, called the pyloric, where it passes out to enter the intestinal canal. It would appear also that the pylorus, or lower mouth of the stomach, has a selective or discriminative power, whereby it freely permits the digested chyme to pass out, but refuses exit to the undigested matter. The chyme having passed into the first part of the intestines, or *duodenum*, is then mixed with the bile from the gall-bladder, and with the pancreatic juice. Both these substances, especially the bile, seem essential for the conversion of the chyme into proper alimentary matter; but their peculiar action has not yet been satisfactorily explained. That the liver and bile ducts are of the utmost importance, however, cannot be doubted, from their magnitude, and the care with which they are supplied with numerous vessels, and from their being universally present in a great proportion of animals. The chyme having passed through the duodenum, and having been mixed with the bile and pancreatic juice, now changes its appearance and properties, and becomes

the chyle, or nutritious matter destined to supply the various parts of the system with nourishment. The digested mass is passed gradually along the course of the small intestines, urged forward by what is called their *peristaltic* motion, which is effected by a successive contraction of their fibrous coats. Here the minute terminations of the lacteal vessels absorb the chyle, and carry it, as has already been described, to the receptacle of the chyle, and then by a duct running up the chest along the spine, called the *thoracic duct*, it joins the blood-vessels. The refuse of the aliment which has not been taken up by these lacteal vessels passes on through the large intestines, and at length is ejected from the body. Digestion is not brought about, as has by some been supposed, by any mechanical means, as by the grinding powers of the coats or sides of the stomach, nor by heat alone, nor fermentation, nor by the simple resolution of the food into a fluid; but it is evident that it undergoes a series of chemical actions in the stomach and bowels, whereby its nature and properties are completely changed; and thus animal and vegetable substances, however different, are reduced to one peculiar kind of fluid, the chyle, which, though it may be found to vary slightly according to the kind of food, is, in its general properties, always the same. The gastric juice varies in different animals. In those which feed on vegetable matter, it dissolves these substances only; whereas grain and vegetables pass through the stomach of a purely carnivorous animal without undergoing any change. The gastric juice has this singular property, too, that although it readily dissolves dead animal matters, and reduces them in a short time to a thin pulp, it will not usually act on the living fibre; so that, after death, the coats of the stomach have been found dissolved into holes, by the same juice which, in the living healthy body, had no such effect.

A stomach of some kind or other is found in all the more highly organised animals; for it is by this organ that nutrition and growth are solely promoted. There are some very simply formed animals, whose whole body consists of little more than an oval hollow bag or stomach, with a simple outlet for the mouth to take in nourishment. The common polypi have a mouth and hollow stomach, with several tentacula or arms, by which the creature seizes the worms and shell-fish on which it feeds; these it swallows, the soft parts are digested, and the animal then voids the remainder from its mouth. The common leech has its whole body divided into a number of small cells; and these receive the water, the juices of plants, and sometimes blood, on which it feeds. Flesh-feeding animals have a simple bag for a stomach, and their food is easily and soon digested. Those animals, again, that feed on grass, which is of more difficult digestion, have three and four stomachs, into which the food successively passes after it has been masticated or chewed a second time in the mouth. This is the case with cows, sheep, deer, &c. Birds that feed on grain have first a sap-bag or crop into which the food enters, and remains for a considerable time, mixed with a juice somewhat like saliva: here it is softened and rendered moist, preparatory to its passing into the true stomach, or gizzard, which is an extremely strong muscular bag; in this, with the assistance of a number of sharp-pointed pebbles, which such birds always swallow, it is ground down and acted on by the gastric juice. This compensates for the deficiency of teeth in fowls. Crabs and lobsters have no teeth in their mouths; but in their stomachs will be found three or more teeth, which assist in grinding down the tough sea-weed on which they feed. By domestication, the qualities of the gastric fluid may be so changed, that animals accustomed to live entirely on flesh will exist and thrive on a vegetable diet. This is the case with dogs and many species of birds. All these peculiarities in the natural history of animals illustrate, at least directly, the uses of the digestive organs in the human beings.

THE LIVER, ETC.

The Liver.—Opposite the stomach, on the right side, lies the liver, a large flat substance, of a dark-brown colour, divided into two lobes. The liver has a round, convex upper surface, and is hollow or concave below; it is also thick and solid at the back part, and its edge becomes thinner towards the front, where it lies over a portion of the stomach and bowels. It is suspended in its place by several ligaments attached to the surrounding parts. In the under side of the liver, in a small hollow, is situated the gall-bladder, a small oval bag which contains the *bile*. A tube from this bladder, called the bile-duct, passes into the upper portion of the bowels, carrying the bile there. The liver is supplied by several branches of an artery in the usual way that the other organs are, but it has also a peculiarity which no other organ of the trunk possesses. The large veins, which return the blood from the lower part of the bowels, before going to the heart, enter the substance of the liver, and there spread into innumerable branches throughout its whole surface. From this venous blood the bile is supposed to be secreted, and after having yielded this substance, the vessels collect again into one large trunk, and join the large vein which carries the blood to the heart. The liver weighs, on an average, from three to four pounds' weight; and the quantity of bile which it secretes, taking into account its large supply of blood, must be very considerable. The greater proportion of animal beings are provided with an apparatus of some kind or other for preparing a supply of bile, and in many the liver bears a large proportion to the other contents of the belly. In some animals, as the horse, the gall-bladder is wanting, there being merely a duct to convey the bile into the intestines. In the lowest classes of animals, all traces of liver or gall-ducts disappear.

The Spleen.—This substance is situated below the stomach, on the left side, betwixt it and the ribs. It is in shape a flat oval, and of a dark iron colour. No duct or opening has been discovered proceeding from it, nor has its use been as yet accurately ascertained. Recent researches seem to indicate that its function is that of a blood-preparing gland. It is remarkable that the spleen has been cut out from living dogs, without causing any apparent derangement in the health or digestion of these animals.

The Pancreas.—This substance, known under the name of the sweet-bread, is a large oblong gland (or *secreting* organ), lying across the back part of the belly, extending between the spleen and the middle of the liver. This gland pours out a substance something like the saliva, and by means of a small duct or canal, empties it into the upper bowels, along with the bile from the gall-bladder, both these substances aiding in digestion, and the preparation of the nutritious fluid to be afterwards mentioned.

Lacteal Vessels.—These are innumerably small tubes, proceeding from the ileum, or small intestines, along their whole course, and spreading along the mesentery, where they form an immense number of small knots, or glands, by joining together. These are the vessels which take up the fluid chyle, or milky-like substance, after it has been digested and properly prepared in the stomach and bowels. From these mesenteric glands, the chyle is conveyed by these ducts or canals to another large gland situated in the loins, on the right side of the aorta, and immediately below the diaphragm, called the receptacle of the chyle. From this receptacle the thoracic duct arises, and passing upward by the side of the aorta, or great artery of the body, it joins the left subclavian vein, lying under the left clavicle or collar-bone, and thus pours the whole of the chyle into the general circulation.

The Kidneys.—These are situated in the loins, one on each side of the back-bone, about one-third up the spine. They are in shape somewhat like a French bean,

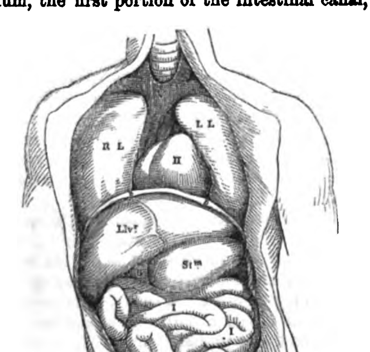
and their internal structure consists of a number of minute porous tubes. They each at the middle hollow part receive a large artery, and their use is to filter from the blood the superabundant fluid, and salts and juices unnecessary for the system, and transmit these by means of two small tubes, called the ureters, to the urinary bladder. These tubes enter the back part of the bladder in a slanting direction, which serves the purpose of valves, preventing a flowing back of the fluid when the bladder is full. The bladder is situated in front, immediately above that bone of the pelvis called the pubis.

The whole cavity of the belly is lined by a thin membrane, called the peritoneum, which is double, being reflected from the sides of the cavity over the whole of the intestinal organs. This peritoneum is liable to inflammation, in the same manner as was mentioned of the pleura, which produces a very violent disease. The coats of the intestines, too, are also subject to the same affection. Dropsy may arise from water being formed between the two folds of the peritoneum.

The Lymphatic Vessels.—These are another distinct set of vessels spread over all the inner cavities of the body, and also throughout the skin. Their office appears to be to take up from the blood a thin lymph, which they convey into the receptacle of the chyle and thoracic duct, and also to absorb moisture from the atmosphere. These vessels are composed of a series of extremely small tubes, and, joining and interweaving, form numerous glands, especially in the groin, armpits, and neck; when swelled by disease, they harden and enlarge, forming knots like a pea or bean. But they are no less numerous on the surface of the inner cavities of the body than on the skin: they are found in the brain, on the surface of the lungs, and in the abdomen or belly. It is a disease or sluggishness of these vessels, whereby they do not perform their necessary duty of taking up all the superabundant fluids, that causes accumulations of water in the chest, belly, and legs. The branches of the lymphatics of the lower half of the body join the receptacle of the chyle; those of the upper part enter the thoracic duct just before the latter pours its contents into the subclavian vein.

THE BOWELS.

From the lower or pyloric orifice of the stomach, the duodenum, the first portion of the intestinal canal, takes



Organs of the Chest and Abdomen.

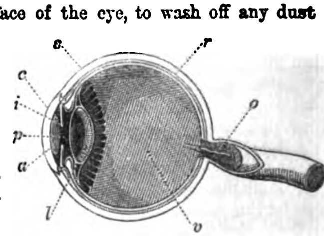
RL, the right lobe of the lungs; LL, the left lobe; H, the heart; V, the great arteries; DD, the diaphragm, a muscle separating the chest from the lower regions; Liv., the liver; Stm., the stomach; G, the duodenum, or beginning of the small intestines; III, the intestines or bowels.

its origin. This gut passes below the liver, and receives the bile-duct, and the duct from the pancreas, when it terminates in the jejunum, which again passes into the ileum, or principal portion of the small intestines. These are of great length, and occupy a great part of the abdomen, being folded and twisted backward and forward in many intricate windings. At the end of the ileum, the colon, a large gut, makes an arch upward towards the right side, and across the belly, and descending at the back part, ends in the short bag called the *cæcum*, which joins the *rectum*, the termination of the intestinal canal. The whole length of the intestines in man is generally about six times that of his average height, or from thirty to thirty-six feet. In all animals that feed on vegetables, the intestines are of great length; whereas in those that derive their nourishment from animal food, they are of much shorter proportions. Two membranous substances, called the *omentum* and *mesentery*, run along nearly the whole length of the intestines, and serve as a means of their attachment and proper suspension in their places. The bowels have three coats—an external one, common to them with the other viscera, a muscular coat, and an internal mucous covering.

THE SENSES.

Man possesses five senses—sight, hearing, smell, taste, and touch—each of which acts through the medium of appropriate instruments, and all regulated by, and acting in connection with, the brain.

Sight—the Eye.—The eye is the exterior instrument of sight, and is a most beautiful and ingeniously constructed object. The eye may be compared in its structure to a telescope, the purpose of both being to collect the rays of light proceeding from the surface of bodies, to concentrate these rays by means of a refracting lens into a focus, and therefore to form a very small image or picture of the object before them. The human eye is placed in a large hollow or socket in the upper bones of the face, surrounded by fatty substance, and the various muscles necessary for moving the eyeball and eyelid. At the upper and outer angle of the eye-socket is placed a gland, which secretes the tears that serve to moisten the delicate surface of the eye, to wash off any dust or other substance, and to keep the ball continually wet and transparent, for the purpose of perfect vision. The tears, after spreading over the eyeball, collect at the inner angle, where, at



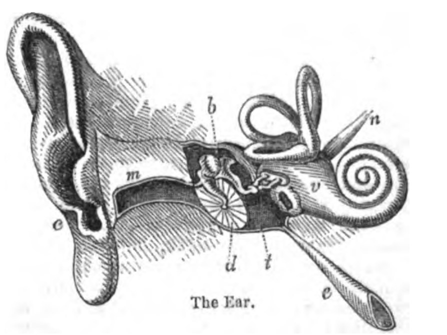
Human Eye Dissected.

each corner of the eyelid, both above and below, there is a small aperture visible, which carries the tears down a passage into the nose. The edges of the eyelids are also supplied with glands, which pour out a mucus that prevents them from adhering together; and these, when irritated and inflamed, are often the seat of disease. The membrane which covers and imparts the white colour to part of the eyeball in front, is called the sclerotic coat (*s*). The middle transparent part of the eye in front is called the cornea (*c*), which is filled with the aqueous humour (*a*) of the eye. Immediately behind the cornea is seen a circular fringed-like substance (*i*), which varies in colour in different individuals, being blue, black, hazel, &c.; hence it is called the iris, or rainbow curtain. This iris has the property of opening and closing, according to the quantity of light which falls upon the eye; and thus the pupil (*p*), a black circle contained within the iris, is enlarged or lessened. Behind the iris is situated the crystalline lens (*l*), in shape resembling the small lens or ground glass of a common telescope, but of unequal swell on each side, being more flattened before than behind. This lens is contained within a capsule, or thin covering of delicate membrane.

A familiar example of the lens of a fish's eye is presented every day in that white globular substance found in such eyes after boiling. The heat coagulates the lens, which is of the same nature as the white of an egg; and in the fish it is nearly a circular body, to adapt the animal's vision to the dense medium of water. The lens is the substance which receives the rays of light entering the eye, and refracts or bends them inwards, whereby they are collected into one point upon the back chamber of the eye or retina, and thus a minute picture of the object seen is formed. If a bullock's eye is taken when fresh, and a hole cut in the skin covering the back part, and then presented to the light with a piece of white paper put opposite the hole, a representation of the objects in front of the eye will be distinctly traced on the paper. When, through disease, the lens becomes of an opaque white colour, and will not transmit the rays of light, the affection is known as *cataract*, producing blindness. The fluid filling the lens is called the crystalline or vitreous humour (*v*). Behind the lens is the back chamber of the eye, filled with a fluid, called, from its thickness, the *crystalline* humour. Over this back chamber the retina (*r*) is spread out like a lining or covering. It is covered over with a black pigment, the better to prevent the intermixture or reflection of the rays of light. On this membrane the optic nerve (*o*), which comes from the front part of the middle brain, and enters the eyeball at the back part, spreads out in numerous branches; and here the small images of the outward objects presented to the eye are painted in miniature. All these objects are painted on the retina in a reversed position, or turned upside down, the same as happens in a common microscope; and how they are perceived in their upright position through the medium of sensation, is a curious question not easily admitting of explanation. Each eye, too, forms a distinct impression of every object; and yet things are not seen double, but both eyes combine to give one impression to the brain or seat of perception. Besides the numerous muscles which roll the eyeball in various directions to adapt it to the various positions of vision, there is also a provision internally by which the crystalline lens is advanced or drawn back, thus adapting itself to the focus of vision in a similar manner as the joints of a telescope are drawn out or pushed inwards. When the cornea is, from its natural form, of too rounded or convex a structure, distant objects are always seen imperfectly, hence causing what is called nigh-sightedness; on the other hand, when it is too flat in form, near objects are then seen indistinctly. This change occurs generally to the cornea as old age approaches; hence spectacles, or artificial rounded lenses, to aid the flatness of the eye, are in such cases made use of with the desired effect. From the different densities of the three humours composing the eye, the refraction or breaking of the light into the various coloured rays is avoided. This, for a long time, was a great objection to telescopes, till different kinds of glass were joined together in the lenses, thus imitating the resources of nature in the eye. The eyes are supplied by two large optic nerves proceeding by separate trunks from the brain; they join together for a short space within the cranium, where they again separate, and each entering an opening at the back part of the orbit, spreads out into branches over the retina. Sometimes these nerves lose their power of sensibility, and total blindness is occasioned without any perceptible disease of the eye; this is called *amaurosis*.

All the higher classes of animals are possessed of evident organs of sight. Birds have in general very acute vision, especially birds of prey, to enable them to distinguish their victims at a great height in the air. They have also a third eyelid, or transparent membrane, which covers the eyeball when they are darting suddenly through the air, and which thus protects the delicate organ of the eye from injury, at the same time that it allows the transmission of a sufficient quantity of light. Fishes have eyes of a somewhat different form from land-animals, to adapt their vision to the denser medium of water, through which the rays of light pass. Insects have great numbers of small eyes or lenses clustered together, like the facets of a gem. Many of the inferior animals—as shell-fish, worms, &c.—have no perceptible organs of vision.

Hearing.—The ear is the instrument of this sense. The outer part or conch (*c*) of the ear is formed so as to collect and transmit the currents of air into the passage (*m*) which leads to the tympanum, or drum (*t*). This passage is defended at its mouth by a number of small hairs growing up in it; there is also a waxy substance constantly secreted, which keeps the whole moist, and is an effectual bar to the entrance of insects or other offensive substances. At the inner end of this winding passage is the thin membrane or drum (*d*), which is stretched out on four small bones (*b*), and which, by its vibrations, conveys through the medium of the nerves the sensations of sound. There are also attached to these small bones several muscles, which,



The Ear.

by their contraction and relaxation, modify the tension of the thin membrane, and prevent sounds from acting too strongly on it, or render it tighter, in order to be even sensible to feeble vibrations. Behind the cavity of the tympanum, or drum, there is another passage which leads from the ear to the mouth, called the *Eustachian tube* (*e*), the object of which is most probably the same as the holes in the common drum—to allow the air to escape from behind, and thus promote the vibration of the membrane of the tympanum; for it is found that if such holes are not made in a drum, little or no sound will be produced; and in the human body, when this tube, leading to the mouth, is choked up by the inflammation of a common cold, deafness is produced. There is another cavity, called the vestibule of the ear (*v*), covered over also by a thin membrane; on this membrane the nerves of hearing are expanded, and convey the sensations of sound to the brain by *n*, the auditory nerve. The sense of hearing is very acute in some animals, especially those that live by prey. In the lower orders of beings, the sense is wanting, but is compensated in a considerable degree by the extreme acuteness of feeling or touch, which is so diffused over their bodies, as to make them sensible of the least agitation in the air by which they are surrounded.

Smell.—The nose is the instrument of smell, and is of comparatively simple structure. The bones forming its inner cavity are of a spongy nature, or rather are composed of a number of very thin plates, covered with a soft membrane, over which the branches of the nerves of smell are minutely exposed. The effluvium proceeding from bodies, indicating their peculiar odour, must pass in a stream or current through the nose before the odour is perceptible. If the air is perfectly still, and no current allowed in the nose, by suspending the breathing through that organ, the strongest smells will make no impression. In some animals the sense

of smell is acute and powerful, beyond the conception of human beings; thus, a dog, by the acuteness of this sense, will distinguish the footsteps of his master amid those of a hundred other people, and can thus trace him for miles, although he has been a long while out of sight; pointers also scent game at a great distance. On the other hand, this sense seems entirely denied to many of the lower animals.

Taste.—The sense of taste is nearly allied to that of smell. The nerves of taste are spread over the upper surface of the tongue, and are raised up in innumerable small points or *papillæ*, like the pile of velvet. Although the tongue is an organ specially adapted to the function of *taste*, this property is by no means exclusively confined to the lingual organ, for the characteristic sensations can also—although in less perfect manner—be perceived by the lining membrane of the palate and back parts of the mouth. That the taste or flavour of many bodies is heightened by the accompanying effects on the organ of smell, is evident; because, if the nose is stopped up so as to prevent the exercise of its functions, many substances having different flavours will taste alike. This is the case with the various kinds of wines, but especially with the ardent spirits. The tongue and whole cavity of the mouth and throat are kept moist by the saliva or spittle, which continually flows into them from repositories placed around the cheeks and under the tongue, called *salivary glands*, which communicate with the mouth by means of small ducts. This saliva flows in greatest quantity during meals, and may even be excited by the sight of food when the appetite is good. It is of essential service in moistening the food, and preparing it for the process of digestion in the stomach. The sensation of taste is in all probability diffused among every class of beings, however low in the scale of existence, although it is probable many animals possess little of it in their mouths, especially when these are formed of hard horny substances, as in many insects, in the lobster, crab, &c., and where any organ corresponding to a tongue is wanting.

Touch.—The sensation of touch is diffused more or less over every part of the body, but is most perfect at the points of the fingers, which in man are generally used to examine the figure and texture of bodies. For this purpose they are furnished with a large supply of very minute blood-vessels and nerves, the latter forming in some situations—according to recent discoveries—peculiar folds within the papillæ of the skin; to these bodies the name of *touch-corpuscle* has been applied. It would appear that there are different nerves that convey the sensation of touch, distinct from those which are the nerves of motion; and that these proceed in pairs from the spinal marrow; and that, moreover, the sensation of heat or cold may be perceived very distinctly in cases where the pricking of a needle or contact of other bodies is never felt. The sense of touch may be said to belong to every animated being, and is one great characteristic of animal life. Vegetables possess a peculiar kind of vitality, and shew what is called irritability of their fibres; but they have no sensation, properly so called. It is probable, however, that sensation is not by any means equally acute in all animals; some feel more intensely than others; and it is a happy provision of nature that it should be so. The lower insects and reptiles, from their structure and habits, are continually exposed to injury; and did they feel it as acutely as the larger animals, the degree of animal suffering throughout nature would be excessive. Many animals bear the loss of limbs with impunity, and some have even the power of restoring these lost members in a very short time. It is probable that according to the perfection of the nervous system, is the acuteness of animal sensation.

On thus reviewing the different parts of the human body, it will be observed that most of its organs are double. On a line being drawn in the middle, on each side will be found parts which are exactly similar to the corresponding side. This is the case with the brain, which is a double organ, having two series of nerves proceeding out from each side of it to go to the respective sides of the body. There are two eyes also, each reflecting a distinct image on the retina; yet the nerves communicate so that only one impression is conveyed to the sense. The arms are double, to suit the various purposes for which they are employed, and so are the lower limbs an essential requisite for the support of the body, and for progressive motion. The lungs, too, may be said to be double, having two distinct lobes; and it sometimes happens that one of them is entirely shrunk or diseased, and yet the important office of respiration is still carried on. The stomach, the liver, and some of the other viscera of the abdomen are, however, single, their several offices being common to the whole body.

THE HAIR AND NAILS.

The hair grows out from the skin somewhat in the manner of a vegetable production. Hairs are fixed by roots in the skin, from whence, by a series of minute vessels, they draw nourishment, and continually increase in length. They possess no sensibility, however, and, unlike the other parts of the frame, may be cut off without producing the least pain. Hair is of different colours in different individuals, being fair in those of light complexion, and deep black in the swarthy. As old age approaches, and even in many young persons, where there is a particular disease in the hair, or dryness in the skin, this colour changes to gray and white. The colouring matter of the hair is principally developed in the centre or medullary portion, and consists of an oily substance, in which carbon, in minute particles, is more or less mingled. The nails are somewhat like hair in their production and composition; they are, like hairs, insensible to the touch, and may be cut or pared without producing pain. They receive nourishment from the blood-vessels of the extremities, and have a constant growth or renewal of their substance. Nails serve as a defence to the tender parts of the fingers; in several classes of animals they form formidable weapons of attack. The horns of cattle are exactly of the same nature as nails, and are chiefly composed of animal gelatine.

The manner in which the various secretions—that are to form hair, nails, wax for the ears, blood, perspiration, &c.—take place in the system, cannot but excite our admiration; for the whole is a chemical process of the most perfect kind, and such as art possesses no power to imitate.

THE SKIN.

An external compact membrane or skin covers the whole body. The outer skin, or cuticle, is unprovided with any blood-vessels or nerves, and consequently is insensible; in this manner it is well suited for a protection to the parts beneath; it is pierced by innumerable minute pores, which are the mouths of the sweat-glands: it is thicker in the palms of the hand and soles of the feet than in any other part of the body. Below the outer skin is a thin membrane called the *rete mucosum*, which, assuming different hues in different nations, gives rise to the variety of colour in the human race. Some have held this membrane to be double, but this is not established. In Europeans, it is white, passing into yellowish brown; in native Americans, of a copper colour; in negroes, of a deep black. The common belief is, that climate has the effect of modifying the colour of the skin, as the black skin only occurs in tropical regions, and it is there found to act as a protection against the scorching influence of the sun's rays. Negroes will remain cool and comfortable exposed to a sun which would be intolerable to a white-skinned person. Their free perspiration seems to be of great service.

Immediately below this net-work is the *cutis*, or true skin, an extremely sensible membrane, so thickly studded with minute blood-vessels and branches of nerves, that the smallest-pointed needle cannot prick it without touching many of them. On the points of the fingers, lips, and other parts of the body, these vessels are very numerous; and hence these parts are endowed with exquisite feelings of touch. Below the skin is situated the cellular membrane, which is a net-work, whose interstices are filled with fat; and it thus serves to fill up the spaces between the muscles, and to make up the shape, and preserve the symmetry, plumpness, and beauty of the whole frame. In cases of emaciation, this fatty matter is sometimes entirely taken up by the absorbent vessels—as after a tedious fever or other lingering disease—when the rough outlines and indentations of the muscles, and the projections of the bones, become painfully apparent.

SLEEP.

The various functions of the body are divided into voluntary and involuntary. When we eat, we perform a voluntary motion; but digestion is performed without the action of the will, or is involuntary. The whole interior functional operations are involuntary, and go on whether we are awake or sleeping.

As a constant supply of food is necessary to repair the waste of the grosser parts of the body, so sleep is essential for the repose and renovation of the finer and more subtile nervous energy. Mere rest alone will not recruit the animal frame; but sleep, or a profound oblivion of feeling and sensation, and every external circumstance, seems essentially necessary at every periodical revolution of the day. Towards the close of a day of exertion, the muscular powers which have been employed in motion, and in sustaining the body erect, begin to suffer particularly: the eyes become dim and heavy, and the eyelids close involuntarily; the lower jaw falls down; the circulation of the blood through the lungs is sluggish, hence frequent yawning is caused; the head nods forwards; all external objects affect us less and less; the thoughts become confused; and at last the profound oblivion of sleep ensues. We are unconscious of the exact moment when we pass into sleep, but occasionally it happens that immediately afterwards we are awaked by a convulsive start, which is caused by the sudden breaking in of the powers of volition, when as yet but newly and imperfectly lulled to rest. Sleep is quite essential to existence. Deprive a person of sleep, and the body sinks under the privation more rapidly than under famine. Indeed, no circumstances, however urgent, will prevent the approaches of sleep for any length of time; and under the severest calamities, and even while in the hour of battle, or when suffering from extreme pain, or cold, or hunger, sleep steals upon us to steep the senses in oblivion. Healthy sleep is so profound, as to resemble, in all that regards self-consciousness, death itself. Sometimes, however, the mind exerts its activity, though it is but a partial exertion; hence dreams, or thoughts of sleep, are made up of all incongruous associations, such as thoughts of the past day and incidents of long bygone years; scenes of actual experience, and others totally imaginary, being all mixed up and jumbled together. In sleep, the heart continues to beat with regularity, and the circulation of the blood is carried on throughout the body; the lungs perform their functions, the stomach digests, and the bowels, and all the glands for secretion, carry on their operations: in short, everything is carried on connected with the sustenance of the body and the existence of the vital powers; but for the most part all other powers, such as those over which we have a control in our waking hours, are at rest. This is not always the case, however, as walking during sleep, or somnambulism, is a peculiarity to which some individuals are liable. Dreams are most common when the sleep is imperfect or too long continued, and thus they occur frequently towards morning, or through the night, if the stomach is loaded and oppressed with food, or the mind harassed and deeply impressed with cares and solicitudes. In a state of health and serenity of spirits, the most profound and most refreshing sleep is during the first period of the night. When asleep, the circulation and breathing are both somewhat slower than when awake, hence the animal heat becomes diminished; and this is the reason why more clothing is required in bed than during the day. This is the reason, too, why a person lying down to sleep out of doors, or on a sofa, with the usual allowance of clothes, feels chill and uncomfortable on awaking. Digestion, too, would appear to go on less vigorously during sleep; and hence the impropriety of going to bed with a full stomach. During the night and darkness, is the most natural and obvious time to select for repose, and it is only the absurd encroachments of fashion that have well-nigh turned day into night. By going early to bed, the damps and colds of night are avoided, which is of essential consequence, especially for the delicate. There is also a natural connection of the functions of the body with the periods of day and night, which makes sleep taken in the first part of the night peculiarly refreshing. The absence of every irritation of the head and other parts of the body—the perfect rest of the mind and external senses—have also great influence in promoting sleep. Again, a variety of causes which weaken and debilitate the body, incline to sleep; such as great losses of blood, cooling medicines, purgatives, coldness of the atmosphere; and narcotics, such as opium and tobacco, drinking largely of wine or spirituous liquors, by first causing great excitement, and afterwards a corresponding debility of the system, also predispose to profound and lethargic sleep. Injuries of the head, by pressing on or otherwise interrupting the functions of the brain, also induce sleep; and great corpulency, by retarding the return of blood through the veins, and thus keeping up a pressure upon the head, is generally accompanied by a disposition to sleepiness.

The period required for sleep by different individuals depends much upon temperament and peculiarities of constitution, as well as on mode of life and habit. While some cannot sleep beyond five, six, or seven hours, others, again, cannot well do with less than eight or nine hours. Children sleep more than half of their time, and require it, and thrive under it; while adults need much less repose. On a general average, eight hours may be reckoned a fair allowance. In order to enjoy grateful and uninterrupted sleep, it is necessary that due exercise shall have been taken during the day; that temperance in food and drink shall have been observed; that strong tea or coffee, which have a stimulating effect on the system, shall not have been taken within an hour or two of going to bed; and that a heavy supper has been avoided. It is true, that gluttony and intoxication produce sometimes deep sleep, but it approaches more to an apoplectic stupor than the calm repose of the temperate.

THE SEXES.

In almost all animals the sexes are distinguished by a difference of form and texture of their bodies; and in many, a superior gloss of colour in the hair or fur, or a superior brilliancy of the plumage, very generally characterises the male of the species. In most animals, too, the males are of superior size, and endowed with greater muscular strength. In the human species, man is marked by a larger and more muscular body than the female; his chest is square and capacious, and particularly at the shoulders, whence it tapers gradually downward; his bones are large, and his joints firm and sinewy; his muscles are round, tense, and conspicuously marked; his limbs thick and fleshy, and his arms powerful; his skin is firm and tense, and his hair strong, crisp, and often curly. The female figure, again, is smaller, less powerful, and in every respect more

delicately formed; the bones are less projecting, the muscles softer, less conspicuous, and more smoothly blended one into the other; the shoulders are narrow and rounded; the greatest breadth of the body being at the pelvis, from whence it gradually tapers upward; the skin is soft and delicate; the hair smooth and of a silken appearance. The mental qualities and dispositions differ somewhat also. Man is commanding, resolute, daring, adventurous, addicted to deep and abstract thought, as well as to high and imaginative speculations. Woman is gentle, submissive, timid: with a mind perhaps little inferior in compass to man, she is more commonly distinguished for acute penetration, nice and delicate discrimination, refined and chastened taste, and elegant and playful fancy. It was the opinion of Plato, that, with regard to the mind, there is no natural difference between the sexes but in point of strength. 'When the entire sexes are compared together,' says he, 'the female is doubtless the inferior; but in individuals, the woman has often the advantage of the man.' With warm and tender attachments, pure morals, and high religious feelings, she is admirably calculated for the sacred charge of watching over and training up the young, and of instilling into their tender and susceptible minds the beautiful lessons of early wisdom—of faith, truth, and charity. All nations, as they have advanced in civilisation, have uniformly increased in that respect and refined attention which is due to the softer sex; and men of the most powerful minds, and of the most splendid endowments, have been the foremost to appreciate those superior qualities which are to be found in a gentle and unsophisticated female.

TEMPERAMENTS.

There are certain conditions of the bodily frame which evidently give rise to varieties of the human constitution, and which have been called temperaments. These have been peculiarly the object of attention to Dr Spurzheim and other phrenological philosophers. As their views on this subject seem to us of a very clear order, a passage is here extracted from one of the journals devoted to that science. 'Dr Spurzheim,' says the journalist, 'recognises four primary or cardinal temperaments, to which he considers all individual cases may be advantageously referred, either as pure, or much more frequently as consisting of two or more combined. I shall first give Dr Spurzheim's brief description of them, and shall afterwards enlarge upon each in detail:

"1. The lymphatic or phlegmatic temperament is indicated by a pale white skin, fair hair, roundness of form, and repletion of the cellular tissue; the flesh is soft, the vital actions are languid, the pulse is feeble, and the whole frame indicates slowness and weakness in the vegetative, affective, and intellectual functions.

"2. The sanguine temperament is proclaimed by a tolerable consistency of flesh, moderate plumpness of parts, light or chestnut hair, blue eyes, great activity of the arterial system, a strong, full, and frequent pulse, and an animated countenance: persons thus constituted are easily affected by external impressions, and possess greater energy than those of the former temperament.

"3. The bilious temperament is characterised by black or dark hair, yellowish or brown skin, black eyes, moderately full but firm muscles, and harshly expressed forms. Those endowed with this constitution have a strongly marked and decided expression of countenance; they manifest great general activity and functional energy.

"4. The external signs of the nervous temperament are fine thin hair, often inclining to curl, delicate health, general emaciation, and smallness of the muscles, rapidity in the muscular actions, vivacity in the sensations. The nervous system of individuals so constituted preponderates extremely, and they exhibit great nervous sensibility."

'The pure lymphatic temperament is characterised by a pallid complexion, soft skin, mostly free from hairs, the hair flaxen, the pulse weak and low; a general tendency to corpulence, and a deficiency of expression in the face. Instances of pure lymphatic temperament are more rare than any of the others, and perhaps are never to be found, except amongst females and habitual invalids, when past middle age, who, from the want of exercise, have lost all trace of some other temperament which they may have possessed in youth. The mental characteristics of the lymphatic temperament are soon told: an insurmountable tendency to indolence, an aversion to exertion of either body or mind, form the hopeful traits. It is therefore obvious that the restraining faculties, Cautiousness and (in some of its manifestations) Secretiveness, are the only organs with the operation of which it will correspond; while all the other propensities, and the intellectual faculties, will be enervated and restrained by it.

'It has been generally supposed that the sanguine constitution is produced by the perfection or redundancy of the circulatory system; and it seems such a natural supposition, that it is difficult for us to allow its proper force to the fact, that individuals of other temperaments are frequently found who can bear loss of blood, by phlebotomy or otherwise, as well as those of sanguine constitutions, and in many instances much better. There is, however, one anatomical peculiarity which appears always to attend the sanguine: the skin is much less disposed to transpiration than the bilious or nervous; and Dr Prichard considers that individuals possessing it are much better calculated to bear cold than others. The Fins, who, as a nation, are decidedly sanguine, bear extraordinary cold winters much better than their more bilious neighbours the Laplanders. Dr Prichard adds, that as the sanguine temperament is very rare in those warmer countries near the spot where man was first placed by his Creator, he considers the sanguine temperament as the result of a natural adaptation to external circumstances, analogous to the white hares and other animals of northern regions; but if this is the case, it is difficult to imagine how the Laplanders should continue tawny, while the Fins, situated further south, are fair. The most striking moral feature of the sanguine temperament appears to be a tendency to enjoyment of the present time, with little inclination to regret the past or to dread the future; and, in general, to look at either past or future no more than is accessory to happiness. The bilious temperament is characterised by a decided cast of features, complexion inclining to brown, dark eyes, and black or dark-brown hair, with the muscles firm and well marked, and the figure in general expressive of vigour, with every motion significant and decided. In combination, it is frequently traced in a slight yellowness of the skin, which can only be detected by comparison, or an extraordinary acute perception of colours; for example, you may frequently find two persons, particularly ladies, the one with dark hair and eyes, the other with flaxen hair and blue eyes. The complexions of both would be denominated fair: on observing them near each other, however, it will be seen that the fairness of the dark-haired one differs considerably from the clear snowy whiteness of the sanguine.

'With respect to the nervous temperament, it manifests itself in a remarkable quickness to learn, and readiness of comprehension, but little tendency to sensual gratification, and an extraordinary power of passing from one subject to another.'

INFANCY—MATURITY.

At the moment of birth, the infant begins to exercise an independent existence, whereas before it formed a part, and was nourished by the vessels of the parent. A general similarity takes place in the embryo growth of most animals, and the familiar instance of the chick in the egg may be taken as an example. The egg is

composed of a centre part or yolk, and of the albumen, or white part surrounding it. In this white part a small darker speck may be seen floating, from whence the first rudiments of the chick are derived. In a few days after the hen has sat on the egg, to impart to it the necessary heat, a small whitish spot will be observed, which is the first rudiments of a brain; in a few days more, vessels will be seen spreading out from a central heart, and forming a net-work all around; gradually an appearance of a head is seen, with indications of brain and spinal marrow; the eyeballs next are formed, then the several parts of the viscera, the projections of the wings and legs; and, lastly, the skin and rudiments of the future feathers. During these periods of incubation the chick has been nourished by the yolk of the egg, which has gradually been absorbed by its vessels for this purpose. At last, when its growth is perfected, and the whole contents of the egg converted into the materials of its body, the little animal begins to pick a hole in the shell, and, by repeated efforts, bursts from its shelly prison, and assumes an independent life.

The infancy of man is of much longer duration, and of a much more helpless nature, than the same state in other animals. A child cannot walk till it is at least twelve months old; and even for a considerable time after that period, it has to be fed and tended with the utmost care; whereas, after a very short time, the young of most animals are able to provide for themselves. A great many, a few minutes after birth, are able to walk about, to search for and distinguish the teat of their mother, and to pick up the food that is suitable for them; and having remained under their maternal protection for a short space, they leave their parents, and never know or distinguish them more. It is very different with the infant: during a long and helpless period of childhood, it is tended by a fond mother, who anticipates all its wants; while it, on the other hand, watches her smiles, and imitates her most minute actions; and thus a reciprocal bond of union is established, by which not only every species of knowledge and experience is acquired for the conduct of after-life, but those moral feelings and sympathies implanted which constitute the great boast and solace of human society.

Man proceeds from infancy to maturity by a slower and more gradual expansion of the bodily structure than any other animal; and this may be one reason of his superior organisation, his greater fitness for supporting labour and fatigue, and the longer period to which his life is extended. From infancy upward the mental powers also gradually expand. This is also different from animals; for in them the faculty of instinct at once is perfected, and never afterwards increases or undergoes any change. In childhood, the mental faculties are constantly active, and on the alert to catch new information, inquisitive to know everything, and imitate every gesture. The facility with which children acquire the knowledge of words, and in a few months master a language, is very astonishing, when we reflect for a moment how much time and pains it takes a grown-up person to become a proficient in any unknown language: and our astonishment will be heightened when we consider that, in the case of children, they have not only to acquire the words and their proper applications, but even to master the articulation of sounds, with all their infinite combinations.

The age of puberty, or that period when boyhood terminates, and manhood commences, varies somewhat in different climates, according to their high or low temperature; the mean period may be reckoned about fourteen years; and between twenty and twenty-five, the growth of the body generally terminates.

About the age of thirty, man may be said to be in his full vigour, with his mental and bodily powers completely developed. Females arrive earlier at a state of maturity than males: in warm climates they are full grown as early as their tenth or twelfth year; in more temperate regions, about their fifteenth or eighteenth year. The proportion of male children born to that of females is as 21 to 20; there is thus a small superabundance of males; but, from various causes, it so happens that there is generally rather a superabundance of females actually existing in society. Among these causes may be mentioned the greater hardships and labours to which men are generally exposed, the devastating effects of war, and, on the whole, the longer life enjoyed by females.

OLD AGE—DECAY.

We have seen that there is within the animal frame a system of operations by which a constant supply of nourishment is afforded to make up for the daily waste and decay, and that every part is constantly undergoing a renewal. To view a man in the full vigour of life, then, we might suppose that, excepting accidents, he was calculated to go on, in the course of existence, for an indefinite period. The principle of life, however, seems to have limits set to its duration, beyond which it fails to keep in healthy motion the animal faculties. The apparatus of life is evidently destined but to last for a certain time. Old age creeps on apace, and the vital flame burns fainter and fainter, till at last it sinks in the socket, and is seen no more. The commencement of decay is perceptible even in youth itself. The child at first grows quickly, from the soft and yielding state of all its vessels; but gradually these begin to thicken and get harder—a greater proportion of earthy matter is adding to the bones. The extremities grow large, while the heart itself does not increase in an equal degree; hence the circulation becomes less and less quick, till the period of full growth. When the growth of the body can proceed no further, a degree of fatness not unfrequently occurs. This proceeds from the superabundant nourishment produced from the food, which, from the impetus or force of the circulation being more lessened by the greater extension and resistance of the body, accumulates in the cellular textures and by the sides of the extreme vessels. In every part of the body the induration produced by approaching age becomes conspicuous—in the bones now wholly brittle, in the skin, in the tendons, in the glands, in the arteries, and in the brain itself, which gets firmer and drier. Moreover, the arteries continue to get denser, narrower, and even shut up in their minute branches. At the same time the nerves become more and more callous and insensible to the impressions of the senses, and the muscles to irritation; thus the contractile force of the heart, and the frequency of its pulsations, are diminished, and, consequently, every force which impels the blood into the ultimate vessels. The quality of humours is diminished in the denser body; the moisture which lubricates the solid parts everywhere manifestly decreases. Nor is the quantity of humours only diminished; they themselves likewise become vitiated. They were mild and bland in children; they are now acrid, salt, and fetid, and loaded with a great quantity of earthy matter. This circumstance of the superabundance of earthy matter is evident in the gouty concretions in the joints of old people, in the frequency of stone, and in the arterial tubes, and even the heart itself, being frequently converted into real bone. The rigidity of the whole body, the decrease of the muscular powers, and the diminution of the juices, constitute old age, which sooner or later comes upon all men—sooner, if subjected to violent labour, or too much addicted to pleasure, or fed upon a too scanty or unwholesome diet; but more slowly, if they have lived quietly and temperately, or if they have removed from a cold to a moderately warm climate.

There are three obvious divisions of human life—a period of youth, including the period before the age of 30; of maturity, from 30 to 50; and of old age, commencing about the period of 50 or 60. The Psalmist

speaks of the age of man being, in his time, only threescore years and ten, or, in rare cases, fourscore years, which may be reckoned the average limit of human existence. After the period of 50 or 60 years, varying of course in different constitutions, the marks of old age begin to make their appearance. The skin becomes more lean and shrivelled; the hair changes to a gray colour, or baldness occurs; the teeth drop out, and in consequence of this, the lower parts of the face, about the mouth and jaws, incline inwards; the muscular motions of the body become less free and elastic—this is especially seen in walking, old people generally treading on the whole base of the feet, and hence having a shuffling gait; the blood circulates slowly; the animal heat is diminished; the pulse occasionally intermits, and the whole energies of the animal frame become lessened; the eyesight begins to fail, and dulness gradually comes over all the senses; the memory undergoes a remarkable change—while recent events pass through the mind and make no impression, the occurrences of early life continually suggest themselves, and are minutely called to remembrance.

Although seventy years is usually the extreme duration of human life, yet a small proportion of those born ever reach even this; a few rare instances occur where 100 years or upward are attained. The famous Parr lived to the age of 159 years; he married at the age of 120; and when 130, was able to thrash, and to do every description of farmers' work. He was at last brought from the pure air and the homely diet of the country into the family of the Earl of Arundel, in London, where he drank wine and lived luxuriously. The sudden change of diet and circumstances, however, proved quickly fatal to him. Henry Jenkins, another poor man, lived to the astonishing age of 169 years, and retained his faculties entire. Some time ago, a statement appeared of the ages of the resident pensioners of Greenwich Hospital, which contained at the time 2410 inmates. Of this number, ninety-six had attained to or passed the age of 80; one only was above 100; fifteen were 90 or more; and eighty were 80 or upward. About forty-two of the ninety-six were of aged families, and in some of this number both parents had been aged. Longevity has in a great number of cases been found to be hereditary. Eighty of the ninety-six had been married; seventy-nine were in the habit of using tobacco in some form or other, and forty-eight had drunk freely; twenty were entirely without teeth; fifty-two had bad, and fourteen good teeth. But the oldest man in the house, who was 102, had four new front teeth within the five preceding years. The sight was impaired in about one-half, and hearing only in about a fifth part of the number.

Old people are not generally inclined for much exercise, nor is it suited to their stiff joints and impaired vigour; for the same reason, they cannot endure much cold. Cheerful company, especially the company of the young, is peculiarly grateful to old people. Innocent amusements and recreations are also of great consequence, and the mind should be exercised in some useful or amusing pursuit. Cities, or, at all events, constant and agreeable society, are favourable to the condition of old age. In lonely secluded country-places, the mind sinks prematurely into a total gloom and blank, for want of sufficient stimulus and variety to keep up the vigour of thought and play of ideas. Few deaths occur from what is commonly called old age, or a gradual and simultaneous decay of all the functions. It may be said to happen when the powers gradually decay, first of the voluntary muscles, then of the vital muscles, and, lastly, of the heart itself; so that in an advanced age, life ceases through mere weakness rather than through the oppression of any disease. The heart becomes unable to propel the blood to the extreme parts of the body; the pulse and heat desert the feet and hands, yet the blood continues to be sent from the heart into those arteries nearest to it, and to be carried back from them. Most commonly, however, some one part gives way, and disease gradually coming on, cuts off the lingering flame of existence. Thus the body, after having grown up to maturity, and flourished in its prime, sinks to the earth, and moulders into the elements of which its several parts are composed.

CONCLUSION.

The admirable structure of the body of the human being, and its superiority in every respect to that of the lower animals, afford a most perfect proof of design in the all-wise Creator, and is one of the most striking instances of the impossibility of our formation being the result of blind chance. Paley, after going over a great number of examples of this kind of design in a Creator, proceeds to state that, in all 'instances wherein the mind feels itself in danger of being confounded by variety, it is sure to rest upon a few strong points, or perhaps upon a single instance. Amongst a multitude of proofs, it is *one* that does the business. If we observe in any argument,' he continues, 'that hardly two minds fix upon the same instance, the diversity of choice shews the strength of the argument, because it shews the number and competition of the examples. There is no subject in which the tendency to dwell upon select or single topics is so usual, because there is no subject of which, in its full extent, the latitude is so great, as that of natural history applied to the proof of an intelligent Creator. Perhaps the most remarkable instances of mechanism in the human frame are the pivot upon which the head turns, the ligament within the socket of the hip-joint, the pulley or trochlear muscles of the eye, the epiglottis, the bandages which tie down the tendons of the wrist and instep, the slit or perforated muscles at the hands and feet, the knitting of the intestines to the mesentery, the course of the chyle into the blood, and the constitution of the sexes as extended throughout the whole of the animal creation. To these instances the reader's memory will go back, as they are severally set forth in their places: there is not one of the number which I do not think decisive; not one which is not strictly mechanical; nor have I read or heard of any solution of these appearances which in the smallest degree shakes the conclusion that we build upon them.

'The works of nature require only to be contemplated. When contemplated, they must ever astonish by their greatness; for, of the vast scale of operation through which our discoveries carry us, at one end we see an intelligent Power arranging planetary systems, and at the other concerting and providing an appropriate mechanism for the clasping and reclasping of the filaments of the feather of the humming-bird. We have proof not only of both these works proceeding from an intelligent agent, but of their proceeding from the same agent; for, in the first place, we can trace an identity of plan, a connection of system, from Saturn to our own globe; and when arrived upon our globe, we can, in the second place, pursue the connection through all the organised, especially the animated, bodies which it supports. We can observe marks of a common relation, as well to one another as to the elements of which their habitation is composed. Therefore one mind hath planned, or at least hath prescribed, a general plan for all these productions. One Being has been concerned in all.'

ZOOLOGY.

ZOOLOGY—a term composed of the Greek ζῶον, an animal, and λόγος, a discourse—aims at classifying animals according to their outward characters and habits.

By outward characters are meant those peculiarities of structure which most conspicuously distinguish animals. Judging by these characters, we can see that some are greatly inferior to others—made, as it were, upon a simpler pattern: for example, worms are simpler than insects, and therefore inferior to them; so, likewise, are fishes simpler than and inferior to poultry and cattle. Hence arises a *gradation* amongst animals, though not of a kind as yet thoroughly ascertained or understood. We can see, however, one clear *principle* in the ranking of animals; namely, that where there are many repetitions of one organ or feature—as, for instance, in the feet of the centipede, or the rays of the feather-star—it is a mark of inferiority, while it is equally true that the concentration of any branch of organisation is a mark of elevation in the scale. We can also trace *analogy* among certain groups of animals, shewing them to be, as it were, comparatively near relations to each other. On gradation and affinity are based all attempts to classify animals.

The first and most important term employed by the zoologist is *species*, as applicable to a certain form and certain characters which remain permanent in successive generations. Thus, the sheep is a species. The honey-bee, also, is a species. The zoologist aims at giving each species of animals a name by which it may be distinguished.

To a number of species having kindred characters, he applies the term *genus*—meaning a kind. A number of genera, again, with more general characters of resemblance, are usually grouped as an *order*. For example, the Ruminant Animals—cattle, deer, &c.—form an order. Sometimes, however, a group of genera, having certain traits in common, is called a *family*; for example, the crow, jay, black-bird, &c., form the family *Corvidæ*. In these instances, a group of families constitutes an order. A *class*, again, is a combination of orders; for instance, Birds are a class. Thus, we come to very general characters; but there are some still more general, according to which we divide the entire Animal Kingdom into four *sub-kingdoms* or *provinces*. Thus we have Provinces, Classes, Orders, Families, Genera, and Species—each term, in succession, being applicable in a more and more particular way than its predecessor. Nor is *species* the last and most particular term, for in many species there are *varieties*. These, however, are regarded as only the transient effect of the conditions in which the species may live.

The four Provinces of the Animal Kingdom are:—1. Radiata, or Rayed Animals. 2. Mollusca, or Pulpy Animals. 3. Articulata, or Jointed Animals. 4. Vertebrata, or Backboned Animals. It is according to these four principal forms that all animals appear to have been modelled—the subordinate divisions being merely slight modifications, founded on the development or addition of certain parts which produce no essential change on the plan itself.

PROVINCE FIRST.

RADIATA.

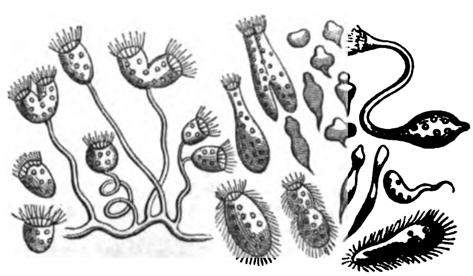
This sub-kingdom was so named by Cuvier, because many of the animals included in it are more or less radiated in plan; that is, exhibit rays or branches. Of all animals, they exhibit the lowest degree of organisation. They are wholly confined to a watery medium or sphere of existence. On account of the obscure form which the nervous system takes in them, some naturalists have proposed for them the name *A'crita* [ἄκριτος, undiscernible]. A number of them, apparently hovering in character between plants and animals, or externally resembling plants, are called Zoophytes (*plant-animals*).

The *Radiata* are divided into five classes—Infusoria, Phytozoa, Acalephæ, Entozoa, and Echinodermata.

CLASS INFUSORIA.

The INFUSORIA are microscopic animalcules; that is, animals so small that they cannot be seen without the aid of the microscope. In all stagnant water, or in any water in which vegetable or animal matter has been infused and allowed to decay, these minute animals are found, being, it is supposed, developed from germs conveyed thither by obscure means. Besides the orders here enumerated, there is a large family of objects, called *Diatomaceæ*, which are not yet with certainty referred to the Animal Kingdom. They consist of single cells, in cases of silex or flint, of numberless forms, found living and moving in all water which has been exposed to the air, and dead in the mud of rivers, in guano, and in many alluvial deposits.

ORDER POLYGASTRICA are the most minute of the ascertained infusory animals. While some species are naked, others are clothed in silicious cases; and it has so happened in the history of the world, that thick strata have been composed of the hard exuviæ of these humble creatures. Though individually invisible to the naked eye, these animals, by their immense numbers, impart a distinct colour to the water in which they swarm, and



Various forms of Animalcules.

they are one of the causes of the phosphorescence of the sea. The order includes two families—*Urcularia* and *Cercarea*.

ORDER ROTIFERA.—These have a gelatinous body, of an oval shape, with a mouth and a stomach. About the head there is a very singular organ, variously divided into tubes with toothed edges, which vibrate in various ways, and when viewed under the microscope have the appearance of one or more toothed wheels revolving with greater or less rapidity. This organ, from which the order derives its name, is supposed to be in some way connected with the function of respiration. The Rotifera are so exceedingly minute, that a drop of water is to them as a lake in which they may disport themselves.

CLASS PHYTOZOA.

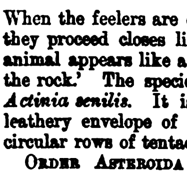
The PHYTOZOA are so named from their external resemblance to plants: they are otherwise called Zoophytes (Animal Plants) and Polypifera. The general

character is that of a small animal or polype, consisting of a stomach, and a mouth surrounded by tentacula (organs for holding).

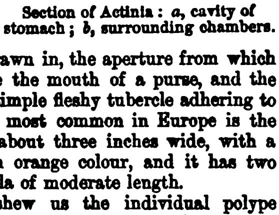
ORDER HYDROIDA have for their fundamental type the *hydra*, a simple polype, usually seen enjoying an independent existence, attached by a stalk to some twig or other object, in stagnant water. The hydra seldom exceeds an inch in length, but is sometimes as long as six inches. The body is wholly gelatinous, consisting only of a kind of bag, which serves as a stomach, with a circle of long arms or tentacula round the mouth. 'Small larvæ, worms, and entomostracous insects seem to be their favourite food; and to entrap these, they expand their tentacula to the utmost, and spread them in every direction, moving them gently in the water to increase their chances. No sooner is their prey laid hold upon, than it evinces every symptom of painful suffering; but its violent contortions are momentary, and a certain death suddenly follows its capture. How this effect is produced, is mere matter of conjecture, as not even a wound can be perceived on the dead animal.'

Hydra.

ORDER HELIANTHOIDA—so named from their resemblance to the popular pictures of the sun and his rays—consists of a variety of fleshy polypes, which have the power of fixing themselves by the base, though many of them also crawl, and allow themselves to be moved along by the current of the water. The family *Actiniidæ* (ἀκτίς, ray, and εἶδος, form) have the body of a soft gelatinous texture, and often brilliantly coloured. Their tentacula are arranged in several rows around the mouth, having the appearance of full-blown many-petaled flowers, whence they are called sea-anemones and sea-sunflowers. They are among the most highly organised of the class, and feed on shell-fish and other marine animals, which they draw into the mouth with their tentacula, disgorging shortly afterwards the shells and other indigestible parts. 'They are very sensitive to light, and expand or close their tentacula according to the fineness of the day.



Actinia seen from above.

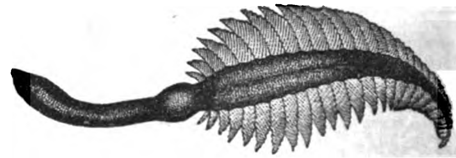


Section of Actinia: *a*, cavity of stomach; *b*, surrounding chambers.

When the feelers are drawn in, the aperture from which they proceed closes like the mouth of a purse, and the animal appears like a simple fleshy tubercle adhering to the rock.' The species most common in Europe is the *Actinia senilis*. It is about three inches wide, with a leathery envelope of an orange colour, and it has two circular rows of tentacula of moderate length.

ORDER ASTEROIDA shew us the individual polype sinking, as it were, under the compound form. One noted family, *Alcyonidæ*, are of a spongy character. They are well known on our coasts under the name *dead-men's-fingers*, and others, referring to their flabby character and the forms they present. What seems a disgusting fleshy mass in the fisherman's net, proves to be, when placed at ease in its proper element, a structure of wonderful beauty. The mass is traversed by a multitude of minute canals, terminating in prominences, from which the polypes protrude.

In the *Pennatula*, or Sea-pen, we see the asteroid



Pennatula.

zoophyte acquiring solid parts. It has a stony axis, flexible at the extremity, and from which a regular series of lateral branches passes off on each side, like the barbs of a feather, each bearing a polype. This genus has a special interest for the geologist, as one of the earliest of fossils, the *graptolite*, evidently belongs to it.

ORDER ASCIDOIDA—called also Bryozoa—comprehends several families and many genera; but it may be sufficient in this place to advert only to a noted species—the *Bowerbankia*. From a sort of creeping stem arise separate polypes, each enclosed in a horny transparent sheath, with ten long and slender tentacula surrounding the mouth. The œsophagus or gullet terminates in a cavity analogous to a gizzard, having thick muscular walls, lined with tooth-like processes. Below this is the true stomach, from which a tube ascends to an outlet near the mouth. The whole economy of this animal, its feeding and lively movements, form a most interesting microscopic study for the naturalist. It has latterly been concluded that the Bryozoa, though bearing a general resemblance to polypes, are entitled to a higher place in the scale of creation. Under the names Foramenifera, Linulites, &c., their microscopic shells are found in enormous abundance in chalk and limestone.

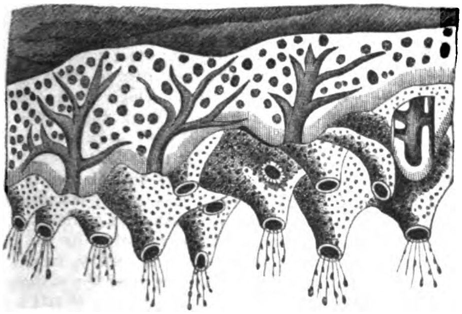
Bowerbankia: *a*, œsophagus; *b*, gizzard; *c*, stomach; *d*, orifice of intestine.

ORDER PORIFERA might be generally described as compound polypes, the individuals being connected by a membrane extended over an internal massive structure, calcareous or horny in its character. In one large family this internal structure is the substance called *coral;* in others, it is that no less familiarly known as *sponge*. The material of coral is secreted and deposited by these animals, and the hugeness of the masses which it forms in some oceans is one of the most wonderful facts in natural history. Extensive reefs and considerable islands in the South Sea are composed of coral, the product of these minute polypes; and the formation named Mountain Limestone is believed to have originated in the same manner.

On carefully examining the Sponge, it is seen to contain a number of minute orifices or pores, extending in channels through the substance. In a living state, when enveloped in membrane, the only vital action that can be traced is a continual passage of water into and out of these channels, being probably for the purpose of supplying the animal with nourishment. In some species, the vents are at the extremities of small protuberances, so that the issue of the water is somewhat like the eruption of a number of volcanoes, but in a downward direction.

In this humble department of creation, the animals are reproduced, not merely by *ova* or germs prepared within the body of the parent, but in various other ways. 'Reproduction by buds [*gemmiparous reproduction*] occurs among the polypes and some of the infusoria. On the stalk, or even on the body of the Hydra, and of

many infusoria, there are formed buds, like those of plants. On close examination, they are found to contain



External surface and sectional view of Living Sponge.

young animals, at first very imperfectly formed, and communicating at the base with the parent body, from which they derive their nourishment. By degrees, the animal is developed; in most cases, the tube by which it is attached to the parent withers away—the animal is detached, and becomes independent. Others remain through life attached to the parent-stalk, and in this respect present a more striking analogy to the buds of plants.

'Reproduction by division, or *fissiparous reproduction*, is still more extraordinary. A cleft or fissure at some part of the body takes place, very slight at first, but constantly increasing in depth, so as to become a deep furrow; at the same time, the organs are divided, and become double; and thus two individuals are formed of one—so similar to each other, that it is impossible to say which is the parent and which the offspring. The division takes place sometimes vertically, and sometimes crosswise. In some infusoria, this division occurs as often as three or four times in a day.'—Agassiz. As already implied, these modes of reproduction are only additional to the universal mode by germs or *ova*.

CLASS ACALEPHÆ.

Acalephæ (ἀκαλήφη, a nettle) are so called from the property many of them possess of irritating and inflaming the skin, the cause of this property being still undiscovered. Cuvier divided the Acalephæ into two Orders, marked by the possession or non-possession of an air-bag to sustain them in the water, calling the former *Hydrostatic* and the latter *Simple*. More recent inquirers arrange them in four groups, named from peculiarities of structure, *Pulmonigrada*, *Ciliograda*, *Cirrhigrada*, and *Physograda*. The most important forms are the *Medusa*, or common jelly-fish, the *Beröe*, and the *Physalia*.

Medusa.—The body of this creature is in the form of a gelatinous disk, more or less convex on the upper surface, somewhat like the head of a mushroom, and termed the umbrella. From the centre of this, and from the margin, there depend in most of the species tentacula, more or less numerous, and elongated. When the Medusa is seen dead on the beach, it appears as a piece of coarse jelly, and it is difficult then to imagine the lively and beautiful movements of the living animal. The solid parts of the Medusa form so small a proportion of its frame, that if a specimen of ten pounds' weight be filtered, the residue will weigh but two drachms! Yet though they are so very soft, they feed upon prey of firm structure—such as crustacea, and other marine animals of much higher organisation than themselves, which, being probably overcome by their stinging power, are quickly seized and dissolved in their stomachs. Many of the species of medusæ are phosphorescent, and when disturbed, shine in the gloom of night like globes of fire.

Beröe.—The species of this family have globular bodies provided with salient bands, extending from the centre of the upper surface to that of the under, and bristled with cilia or filaments, by which their motion through the water is effected. One species, the *B. pileus*, which is understood to constitute a great portion of the food of the common whale, is frequently seen in the English Channel. It has the appearance of a bright globe of jelly, about half an inch in diameter.

Physalia.—The animals of this family have an oblique and wrinkled salient crest on the upper surface, and are furnished below, near one of the ends, with a number of cylindrical appendages. They float upon the surface of the sea when smooth, and the crest answers the purpose of a sail. They are commonly called Portuguese men-of-war, and are often seen in hundreds floating along with the Gulf Stream and other currents of the ocean.

Physalia.

CLASS ENTOZOA.

The Entozoa (ἐντός, within, and ζῶον, an animal) are almost all parasitical on the intestinal organs of other animals. Many of them infest various parts of the human body—as the intestinal tube, the bronchial glands, the kidneys, and the voluntary muscles; and the injury they occasion, when their numbers become excessive, is well known. The habits of intestinal worms are as obscure as their habitations; and the purpose they answer in the economy of nature is quite a mystery. They have colourless blood, circulated in the higher species in a closed system of vessels, without an auricle or a ventricle. They have no visible respiratory organs, no articulated members for locomotion, and no organs of sense. This class admits of subdivision into two Orders—*Nematoidea*, Round-worms, having the intestine floating in a distinct abdominal cavity; and *Parenchymata*, with viscera obscure.

Order Nematoidea (νῆμα, a thread, and εἶδος, form), or Rounded Worms, consist of only one family—the Thread-worms (*Filaridæ*). They are so called on account of the body being long, slender, and threadlike. They are found imbedded between the coats of the viscera, and in similar situations. They are not confined to the larger animals, but are found also in insects and their larvæ, as well as in various mollusks.

The species of thread-worm most dreaded by man is the Guinea-worm (*Filaria medinensis*), which insinuates itself under the skin, generally of the leg, and frequently causes great agony and convulsions. It is about equal in size to a pigeon's quill, and is peculiar to hot countries. The genera of thread-worms, besides the *Filaria* proper, are *Tricocephalus*, *Ascaris*, *Strongylus*, and *Lernea*.

The Order Parenchymata have cavities for the reception of food, carved out, as it were, of the soft, almost homogeneous, tissues of their bodies. Some of them are of eel-like form; such are the so-called *eels* in vinegar, and certain little parasites found in the muscles of man. To this group also belongs the *Tænia* or tapeworm, a creature composed of an indefinite series of parts, all connected by one alimentary canal, but having reproductive organs on each part, and which has been known to reach many yards in length. A head, with four mouths, surrounded by a double circle of small hooks, enables the animal to attach itself to a nourishing surface; and should all the parts except a small number be broken off from the head, new ones will be formed, and the individual animal will continue to live.

One of the most simple of all the entozoa is the *hydatid* or *acephalocyst* (headless bag), a mere sac or stomach with a mouth, which infests the liver and other organs of various animals, including the human species.

The young hydatids grow in the interior of the parent, which perishes when they come to maturity. Allied to this animal is the *distoma* or *fluke*, which infests the liver of sheep, and gives rise to severe disorders. The *Planaria* is a similar parasite, but residing in the water, where it attacks the surface of various animals. In the forepart of its body are two specks, believed to be eyes; a sucker, or mouth, is in the centre; and the reproductive apparatus is behind. Each of these parts, when separated, speedily becomes a complete animal.

CLASS ECHINODERMATA.

Echinodermata (ἐχῖνος, urchin, and δέρμα, a skin), or Spiny-skinned Animals, are so called because they have a crustaceous or coriaceous covering, generally armed with tubercles or spines like that of the hedgehog. They are all marine, and in their adult state move freely about. There are two Orders: those with feet or vesicular appendages, answering the same purpose; and those without them. These are respectively termed *Pedicellata* and *Apoda*.

Order Pedicellata (*pedicellus*, diminutive of *pes*, foot) consist of three well-defined families—Star-fishes, Sea-urchins, and Sea-slugs.

The family of Star-fishes, *Asteriadæ* (ἄστρον, a star), are so called because the body is generally in the form of a star, with rays springing from a central disk, in the middle of the lower side of which the mouth is situated. The framework of the body is composed of horny plates, variously arranged. Through each orifice, the animal can protrude a tubular organ, capable of adhering to the surface of any body. These enable them to draw prey towards their mouth, and are also subservient to the purpose of locomotion. Professor Rymer Jones says: 'If the common star-fish of our coast, which, when it is left by the retiring waves, appears so incapable of movement, be placed in a large glass jar filled with its native element, hundreds of feet will gradually protrude, and fix themselves to the sides of the vessel as the animal begins to march.' They feed upon almost any organised substance, living or dead, that falls in their way.

The family of Sea-urchins or Sea-eggs (*Echinidæ*) have the body covered with a crust of calcareous matter, in segments nicely adapted to each other, and perforated by regular rows of holes for the membranous feet; and the mouth, as in the star-fish, is generally directed downwards. Their food is of a mixed character, consisting of crustacea and sea-weed. The most common of the sea-urchins, properly so called, is the *Echinus esculentus*. This species, which is found in all European seas, equal in size to an ordinary apple, is closely set with short spines, and is generally of a violet colour.

The family of Sea-slugs (*Holothuridæ*) have an oblong body, resembling a cucumber, with a leather-like covering open at both ends. In tropical seas they are very numerous, and many of them are splendidly coloured. Some of the species are edible, and, when dried, are the trepang of commerce. By the Malays they are diligently sought after, for the supply of the China market.

Order Apoda resemble the Holothuridæ in form, but want the feet (ἄπους, without feet); and their leather-like skin is quite unarmed. In their movements they resemble worms; some are found under stones, while others burrow in the sand.

PROVINCE SECOND.

MOLLUSCA.

The term *Mollusca* (from *mollis*, soft) was applied by Cuvier to a large department of the Animal Kingdom, composed of animals having no skeleton, internal or external, but possessing soft bodies, usually enclosed for protection in a shell. The muscles are simply attached to various parts of the skin, and by alternate contractions and expansions of that covering, enable the animals to creep, climb, swim, burrow, and seize upon various objects, according as the form of their parts may permit. Mollusks, however, are generally sluggish in their movements.

The greater number of Mollusks are constant inhabitants of the sea; many, however, live in fresh water, and some dwell upon the land. Their blood is pale, and never truly red. Nearly all of them have an extensive fold of the skin reflected over their body, which it covers like a mantle. It is sometimes extended into a breathing-pipe, or branched and divided in the form of fins. When the covering is simply membranous or fleshy, or when a horny or testaceous rudiment of a shell is developed, but remains concealed in the substance of the mantle, the mollusk is said to be *naked*. When the shell is so much enlarged that the contracted animal finds shelter beneath it, the species is said to be *testaceous*.

The nervous system of the Mollusca is unsymmetrical, being composed of a ring enclosing the gullet, and connected with ganglia or nervous masses in other parts of the body.

Some of the Mollusca are exceedingly small; so much so, that they will pass through holes pricked in paper with a needle. Others are of large bulk; the Tridacna or Clamp-shell, for instance, reaching the weight of 500 pounds. Some of them are of humble organisation, verging on the character of the radiated tribes; others, again, possessing the rudiment of a skeleton, are considered as making an approach to the Vertebrata. The shell is a membrane, composed of minute cells, in which is deposited calcareous matter, the whole being secreted from certain portions of the organisation of the animal. It is either in one piece, or in two, giving rise to one leading term of classification—namely, *univalves* and *bivalves*. The bivalve mollusks are the humbler of the two divisions; from being deficient in a head, they are comprehensively termed Acephala (ἀκέφαλος, headless, from α, privative, κεφαλή, the head).

The formation of the shell is a curious process, depending entirely on the mantle. The margin of this integument is provided with glands, and sometimes also with a fringe of minute tentacula. The animal extending the border of its mantle to the border of the shell, deposits there a fresh layer of cells, containing calcareous matter; thus, layer after layer, it extends its living mansion, in just proportion to its own growth. The border of the mantle contains, in some species, patches of colouring matter, secreted in glands, and the shell becomes variously coloured accordingly. Ridges and spines projecting from the general outline of the shell, are produced by corresponding expansions of the mantle. After the coloured exterior deposit has been formed, the animal thickens it by an interior lining, formed of matter secreted from a different portion of the mantle, and nacreous (mother-of-pearl) in its character. Should any particle of sand have intruded, or any predaceous enemy attempt to bore through the shell, the deposition of nacreous matter is increased at that spot, till a globular prominence is formed, presenting beautiful iridescent colours. Such is the history of the formation of those *pearls* which have long been so highly prized by all nations.

The Mollusca are divided by Agassiz into three Classes—*Acephala*, *Gasteropoda*, and *Cephalopoda*.

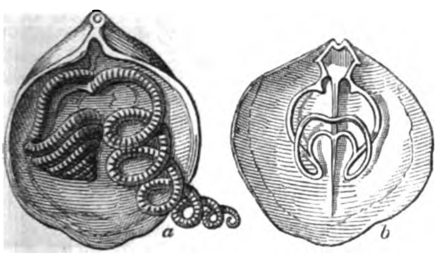
CLASS ACEPHALA.

Order Tunicata.—These are characterised by having the body covered with an elastic cartilaginous tunic, which appears to serve in place of a shell. They are very humble animals, often found associated in strings and clusters, generally unattractive in form, but in some instances transparent and beautiful. One family, the *Ascidians*, has been a favourite subject of study with naturalists. They possess a gill-sac, in which the sea-water is driven about for purposes of respiration, while

the minute particles of food which it contains are at the same time propelled into the stomach. Another curious peculiarity is in the circulation; for after the blood has been sent out for a time by one set of vessels, and received back by another, the process is reversed; and so on alternately.

Among the *Salpæ*, a family of the Tunicata, was first observed the singular phenomenon called *alternate reproduction*. These humble animals, while floating in long chains in the sea, produce each an egg, from which comes a creature, different in form from the parent, and living solitarily. This little animal, in its turn, propagates by a kind of budding, which gives rise to chains seen within the body of the parent, and these again bring forth solitary individuals. Thus each animal resembles, not its parent, but its grandparent.

Order Brachiopoda (Arm-footed) are so called because of their possessing two long ciliated arms, supposed to be used for creating currents, by which food may be brought to the mouth. The valves of their shell are not connected by a hinge, as in the higher acephalans, but by means of certain muscles of the animal's body, by which they are brought together like the boards of a book. The Brachiopoda are dwellers in deep water, are widely diffused over the earth, and make a conspicuous appearance in the earliest fossiliferous strata. The genera *Lingula* and *Terebratula* are fixed by means of a fleshy footstalk to submarine bodies. In *Orbicula*, the pedicle is wanting, and the lower valve of the shell



Terebratula:
a, valve with the spiral arms; *b*, valve with arms removed.

becomes itself the means by which the attachment of the animal to the rock is effected.

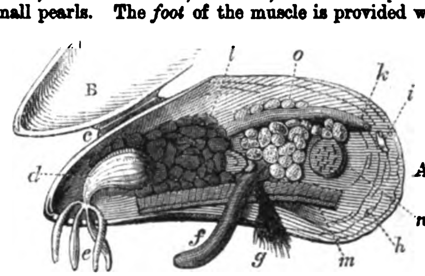
Order Lamellibranchiata (Plate-shaped Gills), or *Testaceæ;* also named *Conchifera:* the latter two names referring to the shells by which they are covered. In this order are included the great mass of bivalves familiar to common observation—as the oysters, muscles, cockles, &c. The most conspicuous peculiarity is the *branchiæ*, or breathing-apparatus, forming a double fringe to each lobe of the mantle, and neatly arranged within the margin of the shell. Another is the *adductor muscle*, by which the animal can draw the valves of its shell close together when it apprehends danger. The shell of a conchifer, unlike that of the brachiopod, has a hinge, which often remains in good condition long after the death or removal of the animal; in some instances, it is made stronger by having *teeth* which lock into each other. In many of the conchifera, there is also a fleshy muscular organ called the *foot*, passing out between the edges of the mantle, and serviceable as a limited means of locomotion.

The Oyster family (*Ostreadæ*).—The edible oyster, *Ostrea Edulis*, has, as the late Professor Forbes remarked, its capital in Britain; for, though found elsewhere on the coasts of Europe, nowhere does it attain such perfection as in our seas. The oyster is deficient in a foot, and is fixed to the sea-bottom by the shell alone. It employs its branchiæ, and the minute cilia with which these are covered, in making currents in the water for the purpose of bringing animalcules to its mouth, which is situated near the hinge, under a kind of hood formed by the edges of the mantle.

In the month of May, the oysters cast their spawn, which the dredgers call the *spat*. It clings to stones, old oyster-shells, and pieces of wood, at the bottom of the sea. It is conjectured that the spat in twenty-four hours begin to have a shell. The oyster is considered full grown for the market when from four to seven years old. Until the third or fourth year, each annual growth is easily observed; but after their maturity, it is difficult to count the layers. Aged oysters become very thick in the shell.

The *Pecten*, so called from the resemblance of the shell to a certain kind of comb, forms the type of a family intimately connected with the oyster, but of higher organisation, being provided with a well-developed foot, and having eye-specks.

The Muscle family (*Mytilaceæ*) are well represented by the common muscle (*Mytilus Edulis*), which is found in great abundance on our shores, usually near the mouths of rivers. Some species are inhabitants of fresh water; and one of these, the *Unio*, is noted for producing small pearls. The *foot* of the muscle is provided with a



Interior of Muscle:
A, right valve; B, left valve; *c*, hinge; *d*, stomach; *e*, tentacula; *f*, foot; *g*, byssus; *h*, branchial orifice; *i*, vent; *k*, termination of intestine; *l*, liver; *m*, gills; *n*, adductor muscle; *o*, ovarium.

collection of hair-like filaments (the *byssus*), by which it attaches itself to solid objects. This curious arrangement, and the other principal parts of the organisation of the muscle, are depicted in the prefixed engraving. Belonging to this family are some remarkable boring mollusks, which have the power of penetrating hard rocks, and making deep holes, which are enlarged as they advance, in accordance with the growth of the animals, and which, therefore, they cannot quit. No mechanical means for producing this effect is observable, and it may be conjectured that the process is of a chemical character.

The Clam, or Spiny Oyster family (*Spondylidæ*), are inhabitants of the Mediterranean and the warmer seas, and are found at various depths attached to coral rocks and dead shells. Their shells, the upper valve of which is armed with spines, are often tinged with lively colours. Several splendid species exist within the tropics.

The Cockle family, *Cardiaceæ* (*cardium*, a cockle), are of numerous species, and the shells of many of them are very beautiful. Cockles are enabled by a large development of the foot to burrow in the sand of the sea-shore.

The *Myadæ* are remarkable for their power of boring and burrowing, so as to form for themselves a habitat. The razor-shell (*solen*) can thus sink a way for itself into the sand with surprising rapidity. Some species of the genus *pholas* are equally noted for their power of boring into wood. Fixing themselves by the foot, they cause their shell to revolve, and thus with its edge cut a way in, the wearing of the instrument being constantly replaced by a fresh formation. They thus serve a useful purpose in destroying waste timber floating in the ocean; but when they attack ships, or wooden sea-works, the mischief done is incalculable.

CLASS GASTEROPODA.

This is an extensive class of mollusks, and perhaps the most typical of their province, since they have its general characteristics, of a well-developed nutritive

system and sluggishness of habits, in the highest perfection. They derive their name Gasteropoda (γαστήρ, the belly, πούς, a foot) from their organ of locomotion, which is a muscular disk projecting from the abdomen, and capable of progression by alternate dilatations and contractions.

Cuvier has arranged the Gasteropoda in nine orders, according to their organs of respiration.

ORDER CYCLOBRANCHIATA (κύκλος, a circle, and βράγχια, gills).—In these gasteropods the gills consist of little tufts or pyramids, attached in a circular arrangement to the inner surface of the margin of the mantle.

The Limpet family (*Patellidæ*).—Among these we find the power of locomotion at its lowest ebb, for they seldom move far from the spot on which they were produced, and many of them, from the shape of the shell corresponding to the surface of the rock, appear never to have left it. The Common Limpet (*Patella Vulgaris*) is universally distributed around our coasts. It subsists on sea-weeds of different kinds, and lives on the surface of rocks and stones between tide-marks. It is sometimes used for food, though much too tough to become a delicacy.

The Chiton family, *Chitonidæ* (χιτών, a garment), are characterised by a series of testaceous symmetrical plates, implanted in the back part of the mantle. Guilding says, these animals live on rocks and stones of the sea-coast, and are distributed nearly over the whole globe. Many species are constantly under water, while others ascend above high-water mark, spending the day exposed to the hottest sun, or resting on spots occasionally moistened by the rude and restless surf. They seem to feed entirely by night. Though they remain stationary during the day, yet when disturbed they will often creep away with a slow and equal pace; sometimes sliding sideways, and creeping under rocks and stones for concealment. If accidentally reversed, they soon recover their position by violent contortions and undulations. They sometimes roll themselves up for defence.

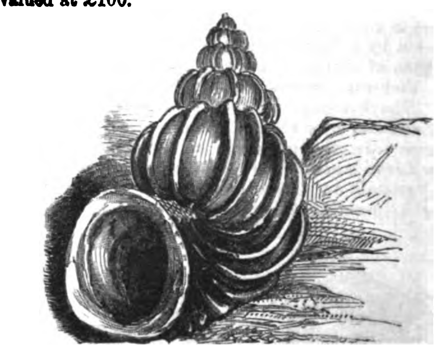
ORDER SCUTIBRANCHIATA (*scutum*, a shield, and *branchiæ*, gills) derive their name from having the gills covered with a shell in the form of a shield. The Ear-shell family, of which *Haliotes* is the type, are furnished with a handsome ear-shaped shell. They are inhabitants of the sea-shore, and live near and under rocks and stones. Their range is south of Britain as far as the Canaries. They are cooked for food; but a more important use of them is in making those mother-of-pearl ornaments which constitute so much of the beauty of works in papier-mâché. Great quantities of Haliotes are brought to Birmingham for this purpose.

ORDER TUBULIBRANCHIATA (*tubulus*, a small tube, and *branchiæ*, gills) are so called from having long tubular snake-like shells, more or less irregular, in which the branchiæ or gills are lodged. These animals are permanently attached to other bodies, and have no power of shifting their station.

ORDER PECTINIBRANCHIATA (*pecten*, a comb, and *branchiæ*, gills).—This is the most extensive order of the class, since it includes almost all the spiral univalve shells, as well as several which are merely conical. The order is thus characterised by Cuvier: the branchiæ, composed of numerous leaflets or fringes, ranged parallel, like the teeth of a comb, are affixed in two or three lines, according to the genera, to the floor of the respiratory cavity which occupies the last whorl of the shell, and which communicates outwards by a wide aperture between the margin of the mantle and the body. They have two feelers, and two eyes, raised sometimes on pedicles, with a mouth in the form of a proboscis, more or less lengthened. Under this order—the species of which are mostly carnivorous—are placed eight Families.

The Trochus family, *Trochidæ* (τροχός, a whorl or top), are so called from the pyramidal shape of their shell, which resembles a top. The whorl for the body is flattened, and the aperture is closed by a horny operculum, or lid. The species are all marine. Some of our most elegant British univalves, and many of the most ornamental exotic shells, belong to this family. They are remarkable for boring into the shells of other mollusks. The buckie is perhaps the best known example.

The Marine Snail family (*Turbinidæ*) are characterised by having a shell of a regular turbinated form, generally much elongated, and a mouth entirely circular. With respect to their habits, it would appear that they frequent submarine banks covered with sea-weed, and are all vegetable feeders. A few are natives of fresh waters, and a limited number respire air. They are found in great abundance in the Indian seas, and are used as food, many being of large size. The winkle is a form of the family with which all are familiar. Another genus, the *Scalaria*, is remarkable for the beautiful and striking form of its shell, one example of which has been valued at £100.



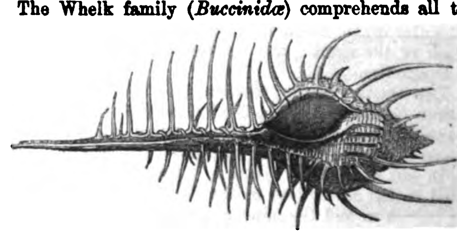
Scalaria Preciosa, or Wentletrap.

The family *Capuloidæ* have a shell with an expanded opening, and but slightly turbinated, without operculum, notch, or a siphon. They do not appear to remove from the spot to which they are first attached, a cavity more or less deep being formed in the surface to which they adhere, either by the chemical agency of some solvent fluid, or by the long-continued operation of currents of water.

The Volute family, *Volutidæ* (*voluta*, a spiral wreath), form an extensive and interesting group, having beautiful shells, but all of them decidedly carnivorous. In the majority, the eyes are sessile, being placed at the extremities of two short tentacula; and the mouth is of a trunk form, and extensile; while the foot in the typical species is of enormous size. They are almost confined to warm latitudes.

The Cowry family (*Cypræidæ*).—From the polish of their surface, and the beauty of their markings, the shells of the Cowries are in considerable request as mantel-piece ornaments, and have been in demand in most countries from time immemorial. The shell of one species of Cowry, *C. Moneta*, is commonly used by the natives of certain parts of Africa, and other semi-barbarous regions, as money. It is yellow, or white with a yellow ring, the margin and base being tubicular.

The Whelk family (*Buccinidæ*) comprehends all the shells which have no fold at the columella or lip, but a notch or a short inflected canal towards the left. The



Murex Tenuispina.

mollusk is of a spiral form, with the foot shorter than the shell. The head is furnished with two tentacles, and the mouth with a proboscis. The common whelk abounds everywhere on our coasts.

The Spindle Shell family, *Muricidæ* (*murex*, the purple-fish), have a univalve spiral shell, with a small oval aperture, ending in a straight or slightly ascending canal. The splendid shell of the *M. Regius*, which is found along the western shores of South America, is one of the ornaments of the cabinet of the conchologist. The Muricidæ, together with the Buccinidæ, appear to be destined to keep in check the superfluous numbers of the bivalve mollusks and herbivorous gasteropods, by drilling their shells and draining their juices.

In the *Strombidæ*, the aperture of the shell is much dilated; the lips expanding, and extended into a groove leaning to the left. The Strombidæ are carnivorous in their habits, and are tenants of the seas of hot latitudes. The number of the species is considerable, and many attain enormous dimensions. In several of them, pearls have occasionally been discovered.

The *Conidæ* form an extra genus or family, comprising many species, one of which, the common *Cone*, possesses a shell of uncommon elegance of form, and rendered additionally attractive by fine colouring.

Order Heteropoda (ἕτερος, different, other, and πούς, a foot).—This order comprehends those gasteropods which have the foot compressed, and in the form of a thin vertical fin. The branchiæ, which are plum-like, are situated on the hinder part of the back, directed forwards; and immediately behind them are situated the heart, liver, and viscera.

The genus *Carinariæ* (*carina*, a keel) are characterised by having the heart, the liver, and the gills protruding from the body, and incased in an extremely fragile and beautiful shell, the convexity of which is terminated by a single keel, whilst the tail is furnished with a sort of fin, which performs the part of a rudder.

The genus *Firoles* in general resemble the Carinariæ; but no shell has been observed. Their snout is prolonged into a recurved proboscis. They are common in the seas of the warm or temperate latitudes.

Order Tectibranchiata (*tectus*, concealed, and *branchiæ*, gills) comprehends those species in which the gills are folliculated on the right side or on the back. These animals are generally covered by a small bubble-shaped shell, concealed in the folds of the mantle. They are all marine, living chiefly on the shore, or on floating sea-weed. They may be further described as thick, fleshy, soft mollusks, generally possessing a distinct head, furnished with a pair of ear-shaped tentacula, and with the mantle usually dilated into two lobes resembling fins, with which they can both

Bursatella Leachii.

swim and crawl. Many of the species are very large, and when taken out of the water appear like great oval masses of flesh. This order consists of two Families. The *Bullidæ* (*bulla*, a bubble) have the shell so perfect as sometimes to be capable of receiving the greater part of the animal, and it is always more or less convolute. The *Aplysianidæ* possess a mere rudimentary shell, resembling one-half of a bivalve. The upper tentacula probably suggested the idea of the ears of the hare; whence the common name of sea-hares given to these animals by the fishermen in most countries.

Order Inferobranchiata (*inferus*, lower, and *branchiæ*, gills) have the gills situated beneath the extended margin of the mantle, and consisting of two long series of leaf-shaped organs. They are incapable of swimming, and are confined to the shore. Their food consists of sea-weed. This order in the system of Cuvier comprehends only two families—*Phyllidia* and *Diphilidia*—of which little is known.

Order Nudibranchiata (*nudus*, naked, and *branchiæ*, gills).—This order of gasteropods, which might be denominated sea-slugs, have the gills exposed on some part of the back, in the form of a rosette, so as exactly to resemble a bunch of vine leaves whose stalks form a common centre. It includes all the naked marine gasteropods, as Triton, Doris, and Tethys. They are generally ornamented with beautiful colours. Besides moving about like other gasteropods by means of their foot, or concave under side, in the depths of the ocean, some species—as the Tritons and Dories—have the power of swimming and crawling on the surface of the sea, with the foot uppermost. In swimming, they are propelled both by their branchiæ and the sides of their body, which act in the manner of fins.

Order Pulmonata (*pulmo*, a lung) Snails and Slugs, the most advanced of gasteropods, are furnished, instead of branchiæ, with a vascular net-work of pulmonary vessels, fitting them to breathe the atmospheric air. Most of them, accordingly, are land-animals; and those which are aquatic—living chiefly in fresh waters and brackish pools—are obliged, like the whales and seals, to come occasionally to the surface to breathe. All the breathing gasteropods feed chiefly on vegetables, and many of them exclusively so; but some are extremely voracious, and will devour almost any organised matter that falls in their way. They are diffused through all climates, particular species being restricted to each.

The aquatic pulmonata have only two tentacula. The family *Lymnæidæ* (Pool Snails) reside in stagnant waters, feeding upon plants and seeds, and having, for the digestion of the latter kind of food, a very muscular gizzard. Another noted family—*Planorbis* (Marsh Snails)—are distinguished by having the coil of their shells upon one plane. They are very common in England.

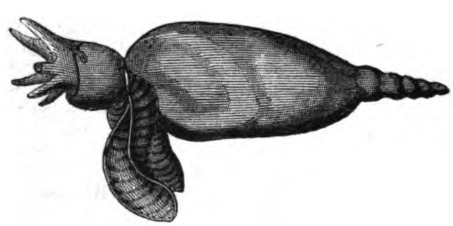
The *Lymnæa* is remarkable from its connection with a very curious phenomenon in the reproduction of entozoa, lately brought to light. The *Cercaria* is a small parasitic animal, a little like a tadpole in form, which, by means of a sucker, attaches itself to the body of the Lymnæa, on which it lives. By and by, while in this condition, it is transformed into a kind of worm, with a double sucker, and is recognised as the *Distoma*. We thus become aware that the cercaria is a transient or immature form of the distoma, as the caterpillar is of the insect. The question arises—What is the origin of the cercaria? It appears that, at a certain season of the year, the viscera of the Lymnæa contain a quantity of little worms, of elongated form, with a well-marked head, and in each of which are clearly to be observed a number of young cercariæ. When these have reached a certain size, they leave the body of the worm, and escape also from that of the Lymnæa, to fasten upon its exterior, there to pass on to the subsequent condition of the distoma. Naturalists call the worm the *nurse* of the cercaria. They further observe these nurses to be the produce of another intestinal worm in the Lymnæa, one longer and more slender, and to which they give

the name of the *grand-nurse*. Supposing these grand-nurses to be the immediate progeny of the distoma, as is probable, we have thus a quadruple series of generations, each presenting an animal more or less peculiar in its form.

The family of *Helicinæ* (Land Snails) are among the most familiarly known of all animals. They possess a shell, generally much thinner than that of the marine gasteropods, and into which they withdraw themselves under apprehension of danger or when at rest. They feed exclusively on vegetables, biting off pieces of the leaves by means of a horny plate attached to the upper lip; and their destructiveness in gardens is well known. The common Garden Snail of this country (*Helix Hortensis*) is much exceeded in bulk by the Great Vine Snail (*H. Pomatia*) of France and Italy, which has also been occasionally found in Britain. More striking examples of the family are to be found in tropical climates, where some species of the genus *Bulimus* attain to so great a size, that their eggs are as large as a pigeon's. In some species, the direction of the coils of the shell is opposite to what it is in other spiral shells; such are said to be *reversed*. Another large snail of tropical climates is the *Achatina*, which feeds on trees and shrubs, and is generally distinguished by the beautiful colours of its shell.

The family of *Limacinæ* (Slugs) are naked or unshelled snails, noted as the pests of gardens on account of their great destructiveness amongst vegetables. The slug has a prominent head, with four tentacula, and at the end of the longer pair the eyes are situated. These tentacula (usually called the *horns*) can be drawn in by a process resembling the inversion of the finger of a glove. On the back there is a kind of shield or disk, which sometimes encloses a small shell, and under which is placed the pulmonary sac or breathing-apparatus.

PTEROPODA are a remarkable group of marine mollusca, which Agassiz places in connection with the Gasteropoda. They are small animals, generally destitute of shells, and provided with wing-like appendages, by which they move through the water; hence their name (πτερόν, a wing; and πούς, a foot). The body is symmetrical, and hence the better adapted for swimming. The Pteropods are found in enormous multitudes; one of them, the *Clio Borealis*, which abounds both in the



Clio Borealis.

Arctic and Antarctic Seas, forms a very important article of food to the whale, which swallows thousands at a mouthful. This little animal is itself eminently carnivorous, and well fitted to seize the minute animals which form its prey. Its six tentacula are provided each with about 3000 invisible filaments, each of which is furnished with about twenty *suckers;* thus each clio is computed to possess 360,000 examples of that form of pneumatic apparatus, for the purpose of prehension or seizing—a complexity of structure considered as perhaps without parallel in the animal creation. When the prey is drawn to the mouth, it is there reduced by a series of sharp thorny teeth, set like those of a comb upon a pair of horny jaws; and it is then drawn into the gullet by the tongue, which is covered with regular rows of spiny hooklets, all directed backwards, and evidently intended to assist in the act of swallowing.

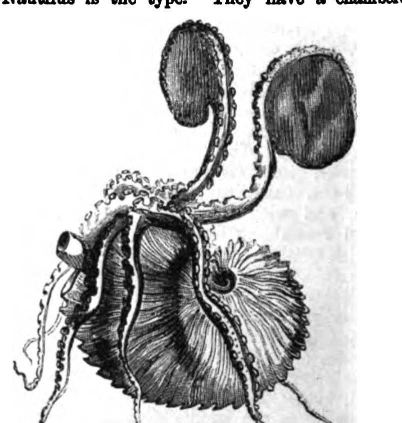
CLASS CEPHALOPODA.

The Cephalopoda are so named from their having their limbs arranged in immediate connection with the head. These limbs, in some eight, in others ten in number, perform all the offices of feet, arms, and feelers, and in many genera are used also as fins. The head, from the arrangement of the limbs, is in the centre, like that of the Radiata. They are, nevertheless, the most highly organised of invertebrate animals, presenting rudiments of an internal skeleton, developed for the purpose of protecting a brain and lodging organs of sight, and, in most of the existing species, organs of hearing. They possess distinct hearts, for the systemic and pulmonary circulations, and highly complicated digestive, secretory, and respiratory organs. The head is large and conspicuous. All the species are marine and carnivorous.

ORDER DIBRANCHIATA (δὶς, twofold, and βράγχια, gills). This order includes those species which have two gills, and are characterised by having three distinct hearts, an apparatus for secreting and emitting an inky fluid, and cephalic arms, never above ten in number, solid, and supporting suckers.

The most typical form of this order is the Cuttle-fish, *Sepiadæ* (σηπία, a cuttle-fish). These animals have immense arms, which are also used as legs; by these they crawl with the greatest facility on the bottom of the sea, swim quickly in the water, and retain a forcible hold of the animals upon which they prey. Their eyes are large, and fully developed, like those of the vertebrated animals. In size, cuttle-fish far exceed all the testaceous mollusks, and may be termed the giants of the Invertebrata. The common species forms the bait with which one-half of the cod-fish is taken off Newfoundland. All the varieties of the Sepiæ yield a dark-coloured juice; and the typical species, *S. Officionalis*, is chiefly sought after for the profusion of fluid which it affords.

ORDER TETRABRANCHIATA (four-gilled) consists of only one family, *Nautilidæ* (ναῦς, a ship), of which the genus Nautilus is the type. They have a chambered



Nautilus.

cell, with simple septa, or divisions, perforated in the centre, concave towards the outlet of the shell, and with the last chamber the largest, and containing the body of the animal.

PROVINCE THIRD.

ARTICULATA.

The *Articulata* (*articulus*, small joint), or Jointed Animals, rank much on a general level with the Mollusca; but being allowed to have a superiority in the nobler

parts of the animal structure, they may be arranged as third, instead of second, in the ascending scale.

They are characterised by having their bodies in segments, and by the greater number of them possessing an external skeleton or case, adapted to the segments of their bodies, and to which muscles are attached. While the vegetative portion of the frame—namely, the organs of nutrition and circulation—are more largely developed in the Mollusca, the organs of the animal powers, the nervous apparatus, and arrangements for locomotion, are more largely seen in the Articulata. They have a symmetrical double nervous cord extending along the whole body, studded with knots or *ganglia*, from which proceed branches to the various segments, and terminating anteriorly in a kind of brain, in the form of a ring surrounding the gullet. The Articulata are consequently distinguished by comparative activity of movement, one large class—the Insects—possessing generally a power of rapid flight in the air. This department of the Animal Kingdom is also noted for the immense variety of its forms, some of its orders presenting many thousands of distinct species.

Professor Agassiz considers the Articulata as capable of being arranged in three Classes—namely, Worms (*Annellata*), Crustaceans, and Insects. The Arachnida, (Spiders), however, which Agassiz would class with Insects, are usually placed separately.

CLASS ANNELLATA.

This is decidedly the lowest form of Articulata. The body consists of a long series of segments, without any hard casing, and without any limbs. They are divided into three Orders, distinguished by their respiratory organs.

ORDER ABRANCHIA (α, priv., and βράγχια, gills), are so called because they have none of the ordinary external organs of respiration, but breathe from the surface of the skin, or, as some suppose, by interior cavities. The greatest part of the animals of this order live at the bottom of the sea, or in fresh water; but a few—like the earthworm—reside in humid ground. The order is divided into two Families—*Lumbricinidæ* (Worms) and *Hirudinidæ* (Leeches).

The Worm family, comprehending the aquatic genus Naiades, and the Earthworms, are remarkable as provided with silky bristles. The common earthworms are of marked importance to the agriculturist, by pulverising the soil, and rendering it more fit to receive the fine fibres of roots and shrubs.

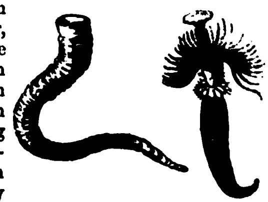
The Leech family (*Hirudinidæ*) have an oblong body; both ends are adapted to fix on bodies by a kind of sucker, by means of which these animals move when out of the water. When in their native element, they swim with facility. Its mouth contains three rows, each armed with a double range of very fine sharp-set teeth, which enable it to pierce the skin without inflicting a dangerous wound. In summer they retire into deep water, and are taken by nets made of twigs and rushes. Leeches are very common in the south of France.

ORDER DORSIBRANCHIATA (*dorsum*, the back, and *branchiæ*, gills) have their gills or breathing organs projecting from the middle parts of the back or sides of the body, where they assume the form of little ramified branches, tufts, plates, or tubercles. The greater number of the species of this order live in the mud, or freely swim in the ocean; but a few, like the next order, inhabit tubes. One of the most interesting families of this order is the *Nereidæ*, or Sea-centipedes, many specimens of which occur on our own coasts. Some of the Nereids exhibit a singular peculiarity in their mode of propagation. The hinder part of the body, being gradually transformed into an additional animal, is cast off by spontaneous division.

A species of the Dorsibranchiates which inhabits the sand (*Lumbricus Marinus*) is very abundant on our coasts, and is dug up for bait by fishermen. It is nearly a foot in length, of a reddish colour, and ejects, when touched, a quantity of yellow fluid. It has three pair of gills.

ORDER TUBICOLÆ (*tubus*, a tube, and *colo*, I inhabit) are so called because they generally occupy tubular sheaths, consisting either of calcareous matter, secreted from their own bodies, or of particles of clay, or of very fine gravel, agglutinated together to serve as a habitation.

The most common Tubicules on our coast are those which belong to the genus *Serpula*. They are found incrusting the surface of stones and shells which have been dredged up from the bottom of the sea. Professor Jones remarks: 'If, while the contained animals are alive, they be placed in a vessel of sea-water, few spectacles are more pleasing than that which they exhibit. The mouth of the tube is first seen to open by the raising of an exquisitely constructed door, and then the creature cautiously protrudes the anterior part of its body, spreading out at the same time two gorgeous fan-like expansions of a rich scarlet or purple colour, which float elegantly in the surrounding water, and serve as branchial or breathing organs.'



Serpula Contortuplicata, taken out of its tube.

Closely allied to the Annellata are the MYRIAPODA or Centipedes, and the IULIDÆ, of which the common Gallyworm is the type.

CLASS CRUSTACEA.

The Crustacea, so called from the hard calcareous case in which they are enveloped, are characterised by a branchial respiration and a dorsal ventricle or heart. From comparative inertness, and large development of the feeding-system, they resemble the Mollusca more than do any of the other articulate classes. They are chiefly marine, and of carnivorous habits. As in insects, the body comprises a head, thorax, and abdomen, which, however, are in some combined in one piece. In the head are compound eyes, a mouth with *mandibles*, frequently furnished with *palpi* or feeling organs, and *maxillæ* in some instances prolonged into a pair of feet. From the thorax proceed four pair of true legs, and one pair of claws, which sometimes reach a large size. The abdomen is also in some families furnished with feet, giving the animal a resemblance to the myriapod. As the investing shell does not increase with their growth, they throw it off periodically, even to the hard facets on the exterior of the eyes, and thereafter a new shell grows upon the soft surface. Cuvier divides this class into two great sections—the MALACOSTRACA (μαλακός, soft, and ὄστρακον, a shell, the term soft being applied in a comparative sense), including all the true calcareous-shelled animals of the class; and ENTOMOSTRACA (ἔντομος, incised), embracing those which have the integuments of the body of slender consistence, and corneous or horny rather than calcareous.

The *Malacostraca* are divided into five Orders.

ORDER DECAPODA (δέκα, ten, and πούς, a foot), a name applied by Cuvier to this order, because they have ten thoracic feet. Most of the species are useful as food.

The family of *Brachyura* (βραχύς, short, and οὐρά, a tail), or Crabs, have the tail or post-abdomen short and folded beneath the trunk. The Edible Crab (*Cancer pagurus*) is the type. In summer, at low tide, they are found in holes of rocks in pairs, male and female; and if the male be taken away, another will be found in the hole at the next recess of tide. By knowing this fact, an experienced fisherman may twice a day take with little work a vast number, after having discovered their haunts. In the winter, they are supposed to

burrow in the sand, or to retire to the deeper part of the ocean.

Crab.

The Land Crabs—called also Violet Crabs and White Crabs, from their colour—are natives of the West Indian Islands and South America. The history of these creatures presents some singular phenomena, from the circumstance of their living in mountainous districts away from sea and water, and inhabiting burrows and holes in trees. During the period of their migration to the sea for the purpose of depositing their eggs, they cover the land in vast multitudes, and spread destruction wherever they go. Their journeys are usually performed during the night.

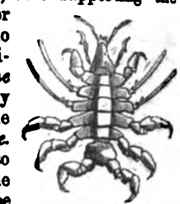
The family of *Macrura* (μακρος, long, and οὐρά, a tail) includes all those ten-footed crustaceans which have the tail or post-abdomen at least as long as the body, and exposed and bent downwards towards the posterior extremity, and always composed of seven segments; and they have at the end of the tail, on each side, appendages ordinarily forming an instrument for swimming. The Macrura may be considered as forming a single genus, *Astacus*. The species are commonly known by the names of Lobsters, Cray-fish, Prawns, and Shrimps.

The family of Hermit Crabs (*Anomoura*) has the abdomen prolonged, but destitute of a shell, so that the tail is soft. They are remarkable for their habit of living in the deserted shells of mollusca, exchanging a less for a larger as they increase in size, and fixing themselves to their strange habitation by peculiar processes which seem developed for the purpose. 'The manœuvres of some of our native species, when they have outgrown their habitation, are quite ludicrous. Crawling slowly along the line of empty shells left by the last wave, and unwilling to part with their now incommodious domicile until another is obtained, they carefully examine one by one the shells which lie in their way, slipping their tails out of the old house into the new one, and again betaking themselves to the old one, if this should not suit. In this manner, they proceed till they have found a habitation to their liking.' They feed upon dead fish, and all kinds of garbage, thrown upon the shore; and when alarmed, they draw themselves closely into the shell, and close the aperture by placing their claws over the entrance.

Order Stomapoda (στόμα, a mouth, and πούς, a foot), commonly called *Sea Mantes*, comprehends crustaceans possessing maxillary feet formed like the first of the thoracic feet. Their gills are naked, and adhere to the five pair of appendages attached beneath the abdomen or tail. These appendages are used in swimming—in other words, they are fin feet. The *Cancer Mantis* is the type of the order; it is about seven inches in length. Its great claws have at the base three movable spines, and the terminal joint has six long and very sharp spines, of which the terminal is the strongest. This species is common in the Mediterranean.

Order Amphipoda (ἀμφίς, on both sides, and πούς, a foot—feet diversely conformed) are small animals, mostly marine, which sometimes are found in brooks and fountains. The majority swim and leap with agility, and always on their sides. The species best known in Britain is the Sandhopper, which burrows in the sand, and seldom enters the water. It feeds on mollusks and fish.

Order Læmodipoda (λαιμός, the throat, and πούς, a foot). These crustaceans have the head confluent with the first segment of the thorax, and supporting the four anterior feet. The posterior extremity of their body exhibits no distinct branchiæ. The Læmodipods are *of small size, all marine animals*, and parasitical; many of them live upon cetacea. The fishermen call them *whale-lice*. Sometimes these creatures are so abundant on the whales, that the individuals they infest may be easily recognised at a considerable distance by the white colour these parasites impart to them. When they have been removed, the surface of the body of the whale is found to be deprived of its outer skin.

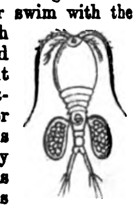


Cyamus Balænarum.

Order Isopoda (ἴσος, equal, and πούς, a foot) comprehends such crustaceans as have the legs all alike, and adapted only for locomotion and grasping. Their bodies are broad and depressed, and they do not leap. The greatest number of the species are aquatic.

The *Entomostraca* are divided into two Orders. The crustaceans of this section are in general so small, that the details of their structure can only be examined by the microscope. The legs, except in a few, are only fitted for swimming, and are variable in their number; some species have only six, others from twenty to forty-two, or even more than a hundred. They mostly inhabit fresh water. The Entomostracans are divided into two Orders—*Branchiopoda* and *Pœcilopoda*.

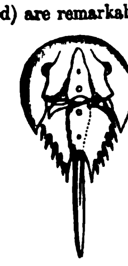
Order Branchiopoda are so named because the locomotive extremities fulfil the functions of gills. The majority of the animals of this order swim with the back downwards, darting about with great agility, and moving backwards and forwards with equal ease. Many exhibit only one eye, as in the family *Monoculidæ* (μόνος, one, and *oculus*, an eye), or Cyclopes. The type of this family is the *Cyclops Quadricornis*. It is very common in the ponds and ditches of this country. One species of this family is found in such inconceivable profusion beyond 42° of south latitude in the Pacific and Atlantic Oceans, that it gives the surface of the sea a red tint, and serves as food for whales.



Cyclops Vulgaris, magnified.

Order Pœcilopoda (ποικίλος, various, and πούς, a foot) includes such Entomostracous Crustaceans as have feet of different forms and uses; the anterior, of indeterminate number, serving either for walking or seizing, and the posterior feet branchial, and fitted for swimming. They live chiefly as parasites upon aquatic animals, and mostly on fishes. This order may be divided into two families—*Hyphosura* and *Siphonostoma*.

The family of *Hyphosura* (web-tailed) are remarkable for having the shield terminated by a very powerful horny, movable spike, like a sword. They are of a large size, sometimes measuring two feet in length. They compose the genus *Limulus* (*limus*, mud), commonly known by the name of King Crabs, or Crabs of the Moluccas, in the neighbourhood of which they are very abundant. They chiefly inhabit tropical seas, and are found near the shore. In China, their eggs are eaten, but their flesh is given to pigs. Savages make use of the horny style at the extremity of the body for arrow-points and spear-heads.



Limulus Polyphemus.

The family *Siphonostoma* are so named from their siphon-shaped mouth, which is fitted for suction. Their shell is very slender, and of a single piece. They are all

parasites, and are known by the name of *fish-lice*. They are found upon perch, pike, and carp. They also occur occasionally upon the cod; but they are never seen within the gill covers.

The **Cirrhopoda** (*cirrus*, a tendril, and πούς, a foot) are a family of Crustacea, of such peculiar and dubious form that till lately they were classed as mollusks. By some naturalists, however, they are considered as a distinct class. They are best known by the appellation of Barnacles. Entirely marine, they, in their mature state, attach themselves to rocks, pieces of floating timber, or the bottoms of ships, and even to the backs of other animals, where they find a diminutive prey. The remarkable feature of their external appearance, which has created such doubts respecting their proper place in the Animal Kingdom, is a many-valved shell, two of the pieces of which greatly resemble those of the common muscle.

This class is divided into two Orders—Barnacles (*Lepadites*) and Acorn-shells (*Balanites*).

The **Lepadites** comprise the Cirrhopods which are elevated upon a fleshy flexible contractile stem, attached by its base to some solid body, and supporting at its extremity the principal parts of the animal, enclosed by a multi-valve shell or leather-like case. The species most widely spread in our seas is *Lepas anatifera*—literally, the goose-producing; a name which records one of the most remarkable delusions of the early observers of animated nature. It was fully believed in the sixteenth and seventeenth centuries, and set forth on many trustworthy testimonies, that a particular species of goose originated in these shell-fish, and this bird was on that account called the *Barnacle Goose*. The authors of this fable must have been misled by some slight and accidental resemblances.

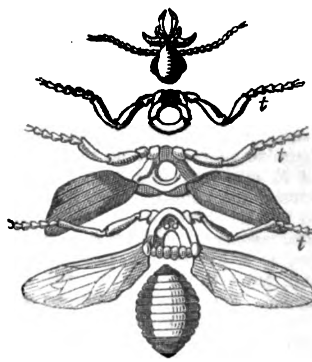
Order Balanites, or *Acorn-shells*.—In these the *shell* is attached to some solid body. In other respects, they differ little from the former order. The rocks, shells, and piers of all our coasts are in a manner covered with a species of the *Lepas balanus*. Others plant themselves on the skin of whales, and penetrate into their lard.

CLASS INSECTA.

The **Insecta**, or Insects, are a class of such endless variety of forms, that zoology would be a great branch of human knowledge if it comprehended them alone. The insect may be described as an articulate animal, with a body of three parts—head, thorax, and abdomen—and three pair of legs; having a peculiar breathing-apparatus of tubes distributed through the body; and generally, but not in all instances, furnished with one or two pair of wings, by which it is enabled to spend a portion of its time in the air. It is also distinguished by undergoing metamorphoses, or changes of form, between its leaving the egg and attaining its adult condition; that is to say, it emerges from the egg into the *larva*, or caterpillar, with all the appearance of a simple grub, in which condition it feeds voraciously and grows rapidly. It then passes into the *pupa* or *chrysalis* state, being cased up in a coriaceous or leather-like covering, like a mummy, and seems all but devoid of life. Finally, it emerges from this condition as the *imago* or perfect insect. There are, however, varieties in these conditions. The larvæ of some insects, for example, reside in tubes which they construct for themselves (the *caddis-worm*); some spin a thread from their bodies, and winding this into a kind of case or cocoon, spend their time therein till ready to come out as perfect insects (the *silk-worm*).

From the great variety of species in the Insecta, and the great fecundity which belongs to most of them, they form a prominent and most important part of creation. 'To leap, to run, to walk, to bore into the ground or drive galleries through timber, to fly through the air, to gambol in the water, to dive and swim, are amongst the endowments of insects. Some build structures more wonderful than the Pyramids, while others construct habitations with mathematical accuracy, and have streets and palaces bearing no slight analogy to those of human communities. Some gleam with phosphorescent radiance, or flutter about painted in all the glories of the rainbow. They furnish us with silk, wax, honey, lac, cochineal, and gall-nuts. Some hold a most important place in the pharmacopœia, and most of them furnish food to the beasts of the earth and birds of the air, to the fish and reptile tribes, and to some of the more powerful of their own class.'

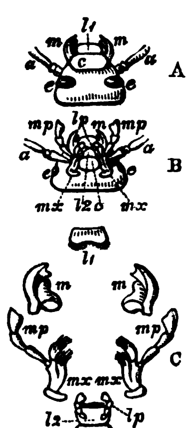
The larva always consists of twelve ring-like sections, exclusive of a head. These twelve sections are still to be traced in the perfect insect, three of them being comprised in the thorax, and the remainder in the abdomen. From each of the three sections of the thorax proceeds a pair of legs, and the second and third usually give origin to a pair of wings each. In the accompanying sketch of the parts of the perfect insect, the three sections of the thorax (*t t t*) are represented apart, with the legs and wings attached to them.



Segments of an Insect.

Insects in their perfect state are distinguished beyond all other animals by their powers of locomotion, and the perfection of their instinctive actions. Their senses appear to be acute. They have generally large eyes, formed by the union of a great number of small ones, presented in different directions, so as to secure a great range of vision. Organs of hearing and smell are believed to exist, though they have not been satisfactorily detected. That there is a delicate sense of touch, is not to be doubted; and from observations made on bees and ants, there is reason to believe that they communicate with each other by this sense. A prominent feature of the head of many insects is a pair of *antennæ*—jointed instruments of various forms—which are evidently used as exploratory organs; of a similar character and similar use are two pair of *palpi*, or feelers, attached to certain parts of the mouth.

In four orders of insects, the mouth is furnished with an apparatus fitted for chewing and bruising the substances on which the animals are intended to feed. In five other orders, there is a proboscis or *haustellium*, for sucking up juices. The first kind of apparatus consists of six principal pieces, the chief being a pair of *mandibles* or cutting instruments, which work against each other, much like a pair of scissors, and sometimes end in hooks, more formidable, for the size of the animal, than the teeth of the tiger. Where, from the presence of a sucking-instrument, the mandibles are not required for eating, they are used variously as trowels, spades, pickaxes, saws, or knives, in the construction of habitations. In the annexed illustration will be found the various parts of the mouth of one of the mandibellate orders—a beetle.*



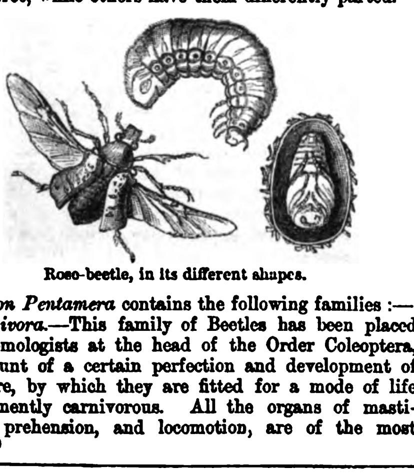
* A, upper side; B, under side; C, parts separated: *aa*, antennæ; *ee*, eyes; *l1*, upper lip; *mm*, mandibles; *mx*, maxillæ; *mp*, maxillary palpi; *l2*, labium; *lp*, labial palpi; *c*, *c*, *c*, chin or mentum.

ORDER COLEOPTERA (κολεός, a sheath, and πτερόν, a wing) comprehends those insects in which the first pair of wings are crustaceous, and serve as defensive coverings to the true wings while at rest, but allow them their proper play when flying. In many instances, however, this is not a correct definition of the order, as some are without wings and sheath; and in many others the latter only is present. The body is also covered with an integument of a similar nature. By means of this crustaceous covering to their wings, beetles are enabled to burrow in the soil, or bore the trunks of trees, without injuring their delicate organs of flight. A beetle, Swainson says, is an insect cased in armour of proof. Let us take a chafer, for instance, or one of those dors whose 'drowsy hum' breaks the stillness of a summer's eve, and examine it closely. With what admirable precision do all the parts of its armour join and fit into each other! It will be almost impossible to insert the point of a pin between any of the joints, and yet the insect moves about without the slightest embarrassment. Not only is every joint, the most minute, either of the antennæ or palpi, completely cased, but even the eyes are often defended in the same manner. They have the hardest covering of all insects—just as the armadillos among quadrupeds, or tortoises among reptiles.

The Coleopterans are, of all the orders of insects, the most numerous and the best known. In Britain, they compose nearly a third part of our entire insect population; and the singular forms and brilliant colours which many of them possess, arrest the attention even of persons comparatively indifferent to the wonders and beauties of nature. With respect to their colouring, an eloquent author says: 'Sometimes they resemble the clouds of heaven; at others, the meandering course of the rivers of the earth, or the undulations of their waters; many are veined like beautiful marbles; others have the semblance of a robe of the finest net-work thrown over them: some she blazons with heraldic insignia, giving them to bear in fields sable, azure, vert, gules, argent or or, fesses, bars, bends, crosses, crescents, stars, and even animals.'

Beetles undergo a complete metamorphosis. The larva envelops itself in silk, makes a covering of leaves; or burrows in the earth, where it undergoes its change into an inactive pupa, and in due course it assumes its last and perfect form. This Linnæus termed *imago*, because, having laid aside its mask, and cast off its swaddling-bands, no longer disguised or confined, or in any respect imperfect, it is now a true representation or image of its species.

The primary division of beetles is founded upon the number of joints in the divisions of their feet, or *tarsi*, as they are called; some having five, some four, and some three, while others have them differently parted.



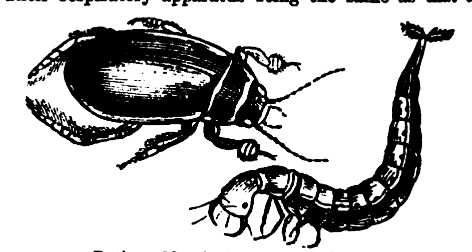
Rose-beetle, in its different shapes.

Section Pentamera contains the following families:—

Carnivora.—This family of Beetles has been placed by entomologists at the head of the Order Coleoptera, on account of a certain perfection and development of structure, by which they are fitted for a mode of life pre-eminently carnivorous. All the organs of mastication, prehension, and locomotion, are of the most efficient kind. Of these the most conspicuous are the mandibles which project from the head, and are armed with strong and powerful teeth. Like the carnivora of the mammals, these insects are remarkable for the beauty of their colours, from which they have derived the name of *Tiger-beetles*. They prey indiscriminately on other insects, and there are few that can resist their attack. Even their larvæ are predatory. In this stage, they dig cylindrical holes for themselves in the earth, nearly vertical. This they accomplish with their feet and jaws; at intervals carrying up the earth they detach on the concave part of their head, and throwing it off by a jerk. In these holes they lie in ambush, ready to seize such unwary insects as come within their reach. 'As the excavation is nearly perpendicular at its mouth, they would have difficulty in retaining their position were it not for their dorsal spines, by which they suspend themselves to the side of their dwelling.' The flat plate of their head exactly stops the mouth of the hole, and forms an even surface with the surrounding soil. When they are about to undergo the change to the pupa state, they seal up the entrance of their dwelling, and retire to its innermost recess.

The Common Beetle (*Cicindela campestris*) is half an inch in length, of an obscure green above, and each elytron, or wing-covering, has five small white dots. These beetles are usually found in sandy fields, or in heaths exposed to the sun. Another beetle of this family is the *Carabus clathratus*, remarkable for its brilliant colours.

Family *Dytiscidæ* (Δύτης, a diver).—The beetles of this family are aquatic in their habits. They have the feet fringed with long stiff hairs, which present a broad surface to the water, otherwise there is little difference in their structure from the former family. Their respiratory apparatus being the same as that of



Dytiscus Marginalis—Larva and Imago.

other insects, they are obliged to repair from time to time to the surface of the water in order to breathe. The larvæ suspend themselves at the top of the pool by means of two appendages at the sides of the tail; but when the period of their transformation arrives, they betake themselves to the land, and burrow in damp situations in the adjacent banks.

Brachelytra are so called from having short crustaceous wing-coverings. Their body is narrow and elongated, and bears some resemblance to the earwig. This family consists of only one genus—*Staphylinus*. One of the largest species of this genus is frequently seen running about garden-walks.

Serricornes (*serra*, a saw, and *cornu*, a horn).—This family comprehends such as have serrated or saw-shaped antennæ, and the elytra completely covering the body. The wire-worm, so well known in this country, is the larva of the *Elator obscurus*. The damage it occasions by devouring the roots of corn is sometimes of vast extent, and attended by most disastrous consequences.

Another interesting genus is the *Lampyris*, or Glow-worm, so remarkable for the brilliant light which it emits at night. The body of this beetle is soft, and the light resides in the two or three last sections of the abdomen. The female especially possesses the luminous property. They are often employed by the inhabitants of those countries where they prevail, as a

substitute for artificial lights. Southey refers to them in his *Madoc*, as furnishing the lamp by which Coatel rescued the British hero from the hands of the Mexican priests:

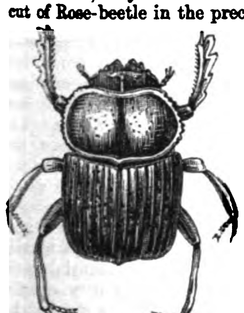
'She beckoned, and descended, and drew out
From underneath her vest a cage, or net
It rather might be called, so fine the twigs
Which knit it, where, confined, two fireflies gave
Their lustre. By that light did Madoc first
Behold the features of his lovely guide.'

The Death-watch (*Annobium pertinax*) derives its specific name from the pertinacity with which it feigns death, 'preferring to be roasted by a slow fire rather than shew the least sign of life.' In the larva state, it employs itself in perforating furniture and books, which, when they have suffered much in this way, are said to be *worm-eaten*. The noise which the little animal makes with its jaws in this work, resembles the ticking of a watch, and is heard whenever an unusual silence prevails. As this is usually the case in a sick-chamber, the noise is apt to be heard before any one dies, and, by a natural process of the ignorant mind, is held to be a warning of death. Hence the name of *death-watch*.

The family *Claricornes* are characterised by having the extremities of the antennæ thick, and often terminated by a perfoliated or solid mass. They are partly terrestrial and partly aquatic. The most remarkable genus of this family are the Burying-beetles (*Necrophorus*), so called from their habit of burying small quadrupeds, such as mice and moles. When they find a carcass, they creep beneath it, and dig away the earth till the hole is sufficiently deep to receive it. After it is intombed, they deposit their eggs in the carcass, upon which the young feed during their larva state.

The family of *Palpicornes* possess, like the last family, long antennæ, terminated in a club, which is commonly leaf-like. The body is generally ovoid. Their feet are suited for swimming. The genus *Hydrophilus* comprises the largest species in the tribe. *H. Piceus* is an inch and a half long, oval, of a black-brown colour. It is common in Britain, frequenting ponds and ditches. It swims and flies well, but walks badly. The females construct cocoons of silk; the outer surface is coated with a gummy matter, which renders it impervious to the water on which they float.

The family of *Lamellicornes* are so called from the antennæ terminating in a club or large knob, composed of laminæ or thin plates, arranged like the leaves of a book, which they can open or shut at pleasure. They feed entirely upon vegetable matter, either in a green or decomposed state. Among them we find great diversity of form, size, and colour. The *Cetonia aurata*, or Common Rose-beetle, may be taken as the type of the whole. See cut of Rose-beetle in the preceding page.

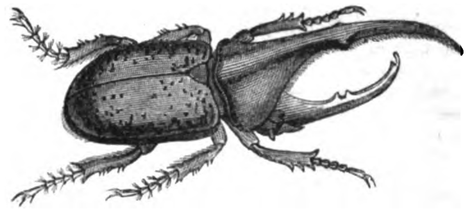


Ateuchus Sacer.

The sacred Egyptian Beetle (*Ateuchus sacer*) was one of the creeping things to which that remarkable people paid divine honours. It was consecrated to the sun, and was therefore regarded as the emblem of fertility.

Some of the best known of our native Coleoptera belong to this family—as the Stag-beetle and Cockchafer. The Stag-beetle (*Lucanus cervus*) is a very large insect, the male measuring two inches in length. It is found in the southern counties of England. It pierces the bark of trees, and lives on the sap. The Cockchafer (*Melolantha vulgaris*) abounds in England, but is rare in Scotland. In its larva state it consumes the roots of grass and other herbaceous plants. The perfect insect is equally destructive to the leaves of our forests and woods.

A most remarkably formed species is the *Dynastes Hercules*, a native of Brazil, which attains the length of five inches, and of which the male possesses an enormous horn projecting from the head, which is opposed by a corresponding protuberance from the thorax.



Dynastes Hercules.

Having described the habits of a few of the beetles, we shall give little more than the classification of the remainder.

Section Heteromera.—The name signifies that the legs have a different structure from one another: while there are five articulations in the first four tarsi, there are only four in the hindmost pair. They are terrestrial in their habits, and chiefly dwell in dark places, such as cellars, stables, and the like. Their food consists of vegetable substances. This section comprises four groups.

Melasoma, as their name implies, are for the most part black, or of an ashy colour, and unvaried. They are distinguished also by hard wing-coverings, wings generally wanting, claws simple, and maxillæ with a hook. They live for the most part in the ground beneath stones, or in the sand, and in low and dark parts of buildings, and are very tenacious of life. The *Blaps mortisaga* is a well-known example, being often found in dark and dirty places about houses.

Another, *Tenebrio molitor*, is very common in England, being found, especially in the evening, in bakehouses and corn-mills. Its larva, called the meal-worm, is long, scaly, and smooth.

Taxicornes (*taxus*, a yew-tree, and *cornu*, a horn) includes those coleopterous insects in which the antennæ gradually augment in size as they extend from the head, or terminate in an enlargement. Their claws are simple, and maxillæ without a hook. They are generally found in the fungi which grow on trees, or beneath the bark. Examples—*Diaperidæ* and *Copyphidæ*.

Stenelytra (στινὸς, narrow, and ἔλυτρον, a sheath) are so called from the wing-coverings being narrow at the posterior part of the body. Examples—*Helopidæ* and *Cistelidæ*.

Trachelides (τράχηλος, a neck).—The insects of this section have the head supported on a kind of pedicle or neck. Examples—*Meloë*, *Mordellattoria*, and *Lagria*. The Blister-beetles (*Meloë vesicatorius*) are more plentiful in Spain than in any other country of Europe, and are well known by the name of Spanish Flies. They are collected for commercial purposes, chiefly in the month of June. They are shaken from the branches of trees and shrubs which they frequent, such as the ash and lilac, and received in sheets spread upon the ground. They are then killed by being held in hair-sieves over the fumes of vinegar, and afterwards dried either by exposure to the sun, or by being placed on hurdles covered with cloth or paper in a well-ventilated apartment.

Section Tetramera contains such beetles as have four joints in each foot. They all feed upon vegetable substances. The perfect insect is found upon the flowers or leaves of plants, while many of the larvæ occupy the interior of fruits or seeds, where they have been deposited by the mother, and furnished with a house of defence and food for their support. This section is divided into seven families, the chief of which is that of the *Curculionidæ*, or Weevils. These are easily

distinguished from other beetles, by the prolongation of the anterior part of the head into a kind of muzzle. They include some of the most dangerous enemies to our vegetable stores. Another family, *Xylophagi*, have their name from the habits of their larvæ as destroyers of wood. A third, the *Longicornes*, are remarkable in the same way; of this family an English species, *Callichroma moschata*, is beautifully coloured, and exhales an agreeable musky odour.

Section Trimera, or the Beetles which have only three joints.—This division is of comparatively limited extent. To it belong *Fungicolæ* (*fungus*, a mushroom, and *colo*, I inhabit); found on mushrooms. A pretty little species of this family found in England is the *Coccinella vigintiduopunctata*, so called from its having eleven white spots on each wing covering. The *Aphidiphagi* prey upon aphides, or plant-lice.

ORDER ORTHOPTERA have the wings, when at rest, disposed in straight longitudinal folds: hence the name. The wing-coverings are called tegmina. These consist of a stiff substance resembling parchment, and serve the purpose not only of protecting the inferior wings, but also of assisting in flight. The Orthopterous insects are terrestrial in all the stages of their existence. Some are carnivorous, or omnivorous; but the greater number feed on living plants. Their mandibles are large, powerful, and efficient.

This order consists of two sections. The first of these, *Cursoria*, have the hind-legs entirely fitted for running, and are divided into four families.

Family *Forficulidæ* (Earwigs) 'are furnished with ample and curious wings, the principal nervures of which are so many radii diverging from a common point near the anterior margin. Between these are others, which, proceeding from the opposite margin, terminate in the middle of the wings. These organs, when at rest, are more than once folded, both transversely and longitudinally.'

Family *Blattidæ* (Cockroaches) are nocturnal insects, certain species of which infest kitchens, bakehouses, and corn-mills, while others are found in the fields. Most of them are of a uniform brown colour; their wing-covers are generally as long as the abdomen, and their wings are folded only longitudinally.

Family *Mantidæ* are characterised by a narrow body, and their legs are unequal; the anterior pair, which are serrated, being longer than the others. They are all carnivorous in their habits, as might be inferred from their large mandibles; and are so pugnacious, that in China the children keep them in small cages, and amuse themselves by putting two together, when they immediately fight like game-cocks. Roësel, who kept some of these insects, observes, that in their mutual

Mantis Religiosa.

conflicts, their manœuvres very much resemble those of hussars fighting with sabres. Sometimes one cleaves the other through at a single stroke of its leg, or severs the head from the body. One species, the *Mantis religiosa*, is regarded by the inhabitants of the countries it inhabits with superstitious reverence, on account of its attitude, recalling the appearance of a man engaged in prayer. This is, however, the position in which the creature lies in wait for its prey. They are chiefly confined to the tropical and warm regions of the globe.

Family *Phasmidæ* (or Spectre Tribe).—This family is distinguished from the Mantidæ by having all the legs of equal dimensions, or nearly so. Their mandibles are, however, adapted for gnawing. They live exclusively on vegetables. This family is rarely found beyond the tropics. Some of the species surpass all other insects in length. *P. Gigas* is said to measure nine inches from one extremity to the other. Another species is remarkable for the similarity its wing-coverings bear to a laurel-leaf.

Section Saltatoria consists of three families.

Family *Achetidæ* (the Cricket Family) are a very noisy race. The chirping of the House-cricket, *Gryllus domesticus*, is heard, under favourable circumstances, at a distance of more than a hundred yards. The noise is produced by the friction of the elytra cases against each other; and though harsh, gives life to solitude, and conveys to the mind the idea of a perfectly happy being; hence the expression, 'as merry as a cricket.' It is found chiefly in bakehouses, and feeds on insects. The Field-cricket and Mole-cricket also belong to this family.

Family of *Gryllidæ* (Grasshoppers) are distinguished by very long antennæ, always as long as their body, and frequently even of greater length. The head is perpendicular, or slightly incurved. They are all herbivorous. Few of them inhabit this country; and such as we possess are of small size, compared with those of foreign lands. These are the little chirpers which we hear in heaths and sunny banks. They begin their song long before sunrise: in the heat of the day it is intermitted, and resumed in the evening.

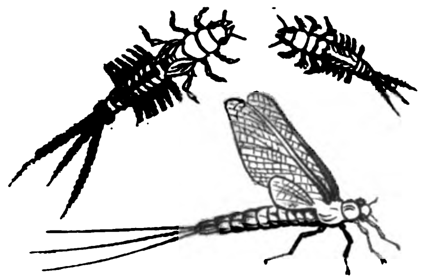
Family of *Locustidæ* (Locusts).—Their antennæ seldom exceed half the length of the body. They have coloured elytra, and large wings, disposed when at rest in straight fan-like folds. They fly by starts, but frequently rise to a great height. 'Certain species unite in vast numbers, and emigrate, resembling a dense cloud in their passage through the air. Wherever they alight, all signs of vegetation disappear, and cultivated grounds are left a desert.'

ORDER NEUROPTERA (Nerve-winged Insects) are characterised by four naked membranous wings, reticulated or interlaced with a delicate net-work, and fully fitted for flight. In general the wings are of an equal length, though in some families the posterior pair are smaller than the others, and in a few cases they are entirely wanting. Some of the Nerve-winged Insects pass through a semi-metamorphosis merely; the rest undergo a complete transformation. The majority of them are carnivorous in the larva state, as well as when they are perfect insects.

The family of *Libellulidæ* (Dragon-flies) are distinguished by the slender form of their body, and beautiful and varied colouring. Their wings are large, and generally extended horizontally, and at right angles to their body during repose. In velocity and protracted duration of flight they excel all other insects, and they can dart backwards or sidewise with equal ease. In the first two stages of their existence, Dragon-flies live entirely in the water; and when they become winged insects, they haunt the precincts of that element on all occasions. At the time of oviposition, the female places herself upon a plant close to the edge of the water, into which she thrusts the extremity of her body and deposits her eggs.

Family *Ephemeridæ* (ἐφ'=ἐπί, upon, and ἡμέρα, a day), Day-flies, are so called from the short duration of their life in the perfect state, which is frequently

limited to twenty-four hours; though as larvæ their existence extends throughout two or three years. They



Ephemera Vulgata—Larva, Pupa, and Imago.

carry their wings always elevated perpendicularly. They are seen in summer and autumn sporting in every variety of evolution over ponds and brooks. The May-flies (*Ephemeres albipennes*) are the largest of the British species, both in the larva state and as perfect insects. They are a favourite food of the fresh-water fishes, and on this account form excellent bait for anglers.

Family *Termitidæ*, White Ants (*termes*, the branch of a tree), are so called because some of them affix their nests to branches. They are terrestrial, and carnivorous or omnivorous in all their stages; and perform a considerable share in the labour of completing the comminution and destruction of dead and decomposing organised matter. They are the only insects of the order that exhibit social habits.

When arrived at their perfect state, the Termites quit their habitation, and fly abroad during the evening and night, but lose their wings before morning, and falling to the ground, numbers of them become the prey of birds and lizards. The workers collect as many of the females as possible, and enclose them in large cells, in order to the establishment of fresh colonies. Although probably all are of tropical origin, a few species have located themselves in the south of Europe.

Family *Myrmelionidæ* (Ant-lions).—The destruction which their larvæ make amongst ants has gained for them their family name. The economy of these insects in their larva state is very interesting. They inhabit dry sandy situations, where they form a funnel-shaped hollow, the top of which is sometimes a foot in diameter, the sides being formed of such loose sand, that any

Ant-lion.

insect approaching the edge inevitably slides down. The ant-lion, having stationed itself at the bottom of the hole with the jaws only exposed, is ready to seize its prey, which, when obtained, it sucks completely dry. Having thus exhausted its juices, the husk is placed upon its head and legs, and a sudden jerk casts it beyond the outer circle of the pitfall. When the ant-lion attains its perfect state, it loses its carnivorous propensities, and revels upon the nectar of flowers. It rarely flies during the day, but chiefly towards the evening. The common European species, in its perfect state, is about an inch in length. Its wings are transparent, black, and dotted with white.

ORDER HYMENOPTERA, or Membrane-winged Insects, resemble the Neuroptera, but cannot well be mistaken for them. The anterior and hinder wings, the former of which exceeds the others in size, are in flight hooked together, so as to produce one continuous margin. These organs exhibit fewer nerves than in the former order. Though considered as mandibulate insects, the Hymenoptera have the maxillæ modified in such a way as to enable them to live in a great degree by suction. A more distinguishing characteristic is perhaps the appendage at the tail, either in the form of a sting or ovipositor. They are distributed over the whole world; and some of them, by their production of wax and honey, are exceedingly serviceable to man. When we add that the order comprises Bees, Ants, Gall-flies, Wasps, and Ichneumons, it will be apparent that the Hymenoptera possess instinct in a higher degree than any other kind of insect.

This order has been divided into the following families:

Family *Tenthredinidæ* (Saw-flies).—The female insects of this family are furnished with an ovipositor—an instrument placed at the extremity of the abdomen, combining the properties of a saw and a file. By its means, the insect makes a succession of small holes in the branches or other parts of trees, in each of which an egg is deposited, accompanied with a drop of frothy liquid, which closes up the hole. Sometimes, however, the ova are attached to leaves. An instance of the former mode of oviposition is observed in the Rose Saw-fly; while a familiar example of the latter is found in the species which infest gooseberry and currant bushes. The larvæ of this family bear a strong resemblance to the caterpillars of butterflies and moths, but are easily distinguished by the number of their feet, being from ten to sixteen.

Family *Ichneumonidæ* (Ichneumons) have obtained their name from the Ichneumon quadruped which destroys the eggs of the crocodile while they are hatching in the sand, and thus limits the increase of that formidable reptile. In a similar manner, the Ichneumonidæ are useful in diminishing the numbers of destructive insects. This family is so numerous, that scarcely an insect exists which in its larva state is not exposed to the attacks of one or other of the species. Inserting their stings into the larvæ of other insects, they there deposit their eggs, where the young, when hatched, find a sufficiency of food. The grub ultimately falls a victim to its ravages; but this event seldom takes place till the young Ichneumons have attained their full growth; and, what is very remarkable, they carefully avoid injuring the vital parts of the larva on which they prey.

Family *Cynipsidæ* (Gall-flies).—These insects deposit their ova in living trees, and the irritation excited by their presence gives rise to the formation of excrescences, called *galls*, such as those so frequently observed on the leaves of the oak-tree. While some of these tumours resemble seed-vessels, others are of a globular form, a bright red colour, and smooth, fleshy consistence, resembling beautiful fruit. Their situation on the plant is also diversified —some being found on the leaf itself, others on the footstalks only; some on the roots, and others on the buds. 'Some of them cause the branches upon which they grow to shoot out in such singular forms, that the plants producing them were esteemed by the old botanists as distinct species.' The larvæ feed on the interior of their habitations, where they generally remain five or six months. Some undergo their metamorphoses within the galls, while others depart, in order to descend into the earth. The small round holes observed in the sides of these excrescences, shew that the insects have made their escape. Galls form an article of commerce; they are imported from the Levant, and used in the manufacture of writing-ink and black dyes.

Family *Formicidæ* (Ants), so celebrated for their industry, live in societies, often of great extent. In this and some other hymenopterous families, there is a curious and peculiar sexual arrangement—one large portion of each society being unfitted for reproduction

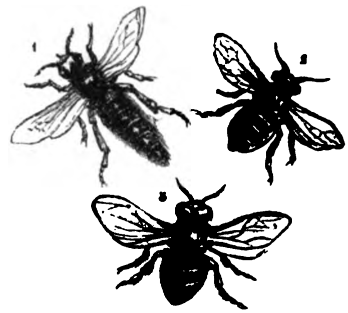
(neuters), and designed only to act as nurses of the young, the production of which is the duty of a limited number of true females. This duty of providing food for, or nursing the young, is what has given ants and bees their great reputation for industry. The males and females are found only temporarily in the ant's nest, from which they make their escape as soon as they have gained their wings. The males soon die. The females pull off their own wings with their feet, and become the founders of new and distinct colonies. The nature and form of the nest vary according to the instinct of the different species. They are most generally established in the ground, the nests being entirely hidden, or forming conical mounds; some inhabit the trunks of old trees, which they pierce in every direction.

The neuters feed the young grubs, and move them on fine days to the outer surface of the nest, in order to give them heat, removing them back at the approach of night or bad weather. They defend them from enemies, and take the greatest care of them and of the pupæ. The neuters pass the winter in their nests in slumber, with more or less pertinacity, according to the severity or mildness of the season.

The food of the ants consists chiefly of aphides or plant-lice. None of the European species hoard grain for the winter, but they display a sagacity no less wonderful in forming a provision for themselves. 'Many of them,' says Huber, 'collect the eggs of aphides, deposit them in their own nest, and guard them with the greatest care till hatched; and then, as we pasture milch kine, they continue to keep an eye over them, for the delicious nutriment they afford.' There is, however, a species in India which hoards up the seeds of grass, and to it the lesson of Solomon may have referred: 'Go to the ant, thou sluggard; consider her ways, and be wise: which having no guide, overseer, or ruler, provideth her meat in the summer, and gathereth her food in the harvest.'—*Prov.* vi. 6–8. Some ants are gifted with double means of annoyance, as they can sting as well as bite. Our indigenous species may be regarded as comparatively harmless.

The *Vespidæ* (Wasps) generally form large societies, composed of males, females, and neuters. A colony is commenced in the spring by a single female, which has lain dormant and survived the severity of winter. She lays eggs which soon produce neuters or labourers. Assisted by a numerous army of these coadjutors, she proceeds to enlarge the nest, by detaching particles of old wood or bark, and moistening and reducing them into pulp. This, when dried, forms a paper-like substance, suitable for the purpose of building. The neuters, under the guidance of the parent-wasp, tend subsequent broods till the beginning of autumn. The young males and females then appear abroad. The number of females in a wasp's nest generally amounts to several hundreds. Of these very few survive the winter; such as are so fortunate, remain torpid till the vernal sun recalls them to life and action.

Family *Apidæ* (or Bees) compose a large group, which are well known from the universal reputation of the typical genus *Apis*, of which the domestic bee is a species. Living in detached communities, under the apparent rule of an individual, the domestic bees furnish us with an emblem of monarchical government, whilst their steady industry in storing up provision for the contingencies of a barren period, has been the theme of sages and moralists, as an example for the indolent of their own species. The average number of each community has been computed at about 16,000. One only of each hive is a true female, distinguished by her size, and denominated the *queen*. About 600 are males, usually called *drones;* and the remainder, consisting of upwards of 15,000, are *neuters*, destined to labour. The queen, in the larva state, is furnished with a cell of royal dimensions, of a cylindrical form, and she is supplied by her nurses with food of the most nutritious and delicate kind, called by bee-farmers royal jelly, extracted from flowery juices. When arrived at full growth, she spins



1, Queen; 2, Drone; 3, Neuter Bee.

within her cell a silken shroud; therein she changes to a nymph or pupa, and in due time comes forth in all the dignity of majestic size and splendid colouring. The labouring-bees find themselves, when emerging from the egg, inhabitants of six-sided cells, so proportioned as to limit their growth, and prevent their full development; they are supported on the simple fare of bee-bread—a substance composed of pollen and honey. The males or drones exist only between April and August, when they are destroyed by the workers as useless.

The wax of which the bees construct the cells required for the storing of their honey and other purposes, is secreted by them in little scales, in which state it works out from between the segments of the abdomen. These are taken up and kneaded by the jaws, and applied in the proper place. The cells are built in a hexagonal, or six-sided form, being that which gives the nearest approach to the circular, with the least expenditure of material, and at the same time the greatest strength. The bottom of each cell on one side abuts against three on the other, and is supported by the divisions between them. It is formed of three plates meeting at an angle, and this angle has been ascertained, by a very intricate calculation, to be *precisely* that which enables the greatest strength to be obtained with the least material; the instinct of an insect thus coming to the very same result as the highest human intelligence. Some of the cells thus formed are employed as store-rooms for honey and pollen, and in others the eggs are laid. The eggs from which perfect females or queens are to be produced, are laid in cells much larger than the rest, and of different form; but if, from any cause, these should not afford a sufficient number, the bees have the power of rearing a female or queen from a neuter grub, by feeding it with an aliment more stimulating than the pollen. The drones are killed at the end of summer, but the queen and great part of the workers remain; and when, in the summer, they increase so much as to over-people the hive, colonies are sent forth with young queens in search of another habitation.

One of the most marked features of the wasps and bees, is the possession of a sting, situated where the ovipositor is placed in other hymenopterous insects.

The remaining orders of insects are *Haustellate*—that is, possessed of a mouth formed for suction.

ORDER HOMOPTERA have the fore-wings of the same consistence throughout, often somewhat parchmenty, and, when folded, they incline at an angle like the roof of a house. All the animals of this order feed on vegetable juices, for obtaining which their tongue is elongated and channeled like a gutter, and surrounded by delicate lance-like organs for piercing the tissue of plants. The females of some species are furnished with an ovipositor, provided with several toothed saws, by means of which they make punctures in the leaves and stems of plants, and thus introduce their eggs into a place suitable for bringing out the larvæ.

Family *Cicadidæ* have their type in the well-known *Cicada*, so much celebrated by the poets for its fine song. Most of the species are confined to warm climates, and only a small one exists in England. The shrill chirp of the cicada is alluded to by many poets. One bard entreats the shepherds, 'To spare that nightingale of the nymphs.' Anacreon calls it 'Sweet prophet of the summer;' and Virgil alludes to it when he says: 'Et cantu querulæ rumpent arbusta cicadæ.' Byron describes them as 'The shrill cicadæ, people of the pine.' No author has given a better idea of the singing of a cicada than old Marcgrave, who says its tune begins with *gir*, *gvir*, and continues with *cis*, *cis*, *cis*. The animal produces its sound by a peculiar apparatus situated beneath the abdomen. Among the Cicadidæ are found the largest of the homopterous insects, some species measuring seven inches across the wings.

Family *Aphides* (Plant-lice) inhabit trees or plants, to which, notwithstanding their generally small size, they prove highly destructive. They are frequently seen on rose-buds, and on the honeysuckle, presenting a green mass of moving life; and the sweet honey-dew which is found on the leaves of these plants, and various other trees, is a substance extracted by these little insects from the sap, and afterwards ejected in a state of the greatest purity.

Family *Coccidæ* (Blight Insects).—The males have only two wings, which lie horizontally on the body, one over the other. The females are without wings. The cochineal insect (*Coccus cacti*), a species of this family, is esteemed for the splendid colour it furnishes. It was first imported into this country from Mexico about the middle of the sixteenth century. The animals are scraped from the cactus plants, which they inhabit, into bags, killed by boiling-water, and dried in the sun. Though the Spaniards, on their arrival in Mexico in 1518, found cochineal dye employed by the natives, yet its true nature was not ascertained for nearly two centuries afterwards. Acosta, indeed, as early as 1530, stated it to be an insect; but Europeans generally, misled by its external appearance—resembling that of a reddish shrivelled grain—believed it to be the seed of a plant. The quantity annually exported from Mexico has been said by Humboldt to realise half a million sterling. It takes 70,000 insects to make a pound of cochineal. Another species, which belongs to the East Indies, produces gumlac, a substance made use of in the manufacture of beads, rings, and other ornaments; mixed with sand, it forms grindstones. In this country it is chiefly employed in the composition of varnishes, sealing-wax, and japanned or lacquered ware. A species in China is used for the manufacture of wax-tapers.

Family *Fulgoridæ* are distinguished by a curious prolongation of the forehead, which sometimes equals the rest of the body in size. In it is said to reside the luminosity which has given rise to the family name—a property, however, which has been doubted by many

Fulgora Laternaria.

naturalists. The species are all vegetable feeders, and greatly destructive. Some species in China make a certain compensation for this by producing a secretion, from which a fine white wax is manufactured.

Family *Cercopidæ* are insects of small size, remarkable for the grotesqueness of the forms which many of them assume. Some species inhabit this country, the larva and pupa being remarkable for causing that exspumation on plants which children call cuckoo-spit or gowk-spittle.

Order Heteroptera are the co-relatives of the Homoptera, being distinguished from them by having the fore-wings of diverse consistence, coriaceous at the base, and membranous towards the point. They are chiefly supported by vegetable juices; but some are remarkable for preying on the juices of the larger animals. The majority are confined to tropical climates, and the species which inhabit these regions are mostly ornamented with a great variety of beautiful colours and markings. In some species the wings are undeveloped, or the upper pair is wanting.

Family *Cimicidæ* (Bugs) are unhappily familiar to us, by the intrusion of a well-known species into our bed-chambers. It is believed that this disgusting insect was brought first to Europe early in the sixteenth century, by the return of the first voyagers from America. It has derived its name—Celtic for a hobgoblin—from its nocturnal and stealthy habits. The bite is generally attended by a poisonous effect, and there is a particular species said to be able to communicate a slight electric shock.

The *Water-bugs*, or *Boat-flies*, haunt the surface of still waters, moving rapidly along on their backs by means of their oar-like hind-legs, and using the front pair, which resemble a pair of hooks, in seizing small aquatic insects. They are furnished with wings, which they use in transporting themselves to new fields of depredation.

The *Nepidæ* (Water-scorpions) are fierce insects which lurk in the mud or weeds of ponds and streamlets, living solely upon insects. They seize and hold their prey with their long lobster-like fore-arms, and pierce it with their beak; a pointed hollow weapon serves the further purpose of sucking the juices of the struggling victim. Their prevailing colour is a blackish brown, scarcely distinguishable from the mud in which they love to lurk. In the twilight they frequently leave the water, for the purpose of seeking elsewhere a similar abode.

Order Lepidoptera (*Moths* and *Butterflies*) derive their name from a conspicuous peculiarity of their wings, the ordinary membrane of these organs being covered with a multitude of minute scales (λεπίς, a scale), set or planted therein, like the tiles on the roof of a house. The colours, which render the wings of many of the order so beautiful, reside in these scales, of which as many as 400,000 are reckoned to exist in a single silk-fly. The Lepidoptera subsist exclusively upon fluid nutriment, for obtaining which the maxillæ are so fashioned that they lock together with teeth into a single tube. All of this order are either males or females; neuters, which are so prominent among the Hymenoptera, are not found in the Lepidoptera. They go through a perfect metamorphosis. From the eggs deposited on the leaves of plants, proceed in due time the larvæ, or caterpillars, each species being generally placed on the kind of plant which it is fitted or inclined to eat. When it has attained its full size, it spins around its body a cocoon or case of silk, in which to spend its life as a *pupa* or *chrysalis*. This is an important habit on the part of the insect, as from one species we derive the silk which we weave into one of the most elegant kinds of cloth. The threads are formed by a glutinous secretion from glands, which seem analogous to the salivary glands of other animals; forced out through a small opening at the end of the lip, it hardens as it dries in the air. Some Lepidoptera form no cocoon, but hang in the pupa state by a thread from some lofty place. At the proper time, the perfect insect bursts from its case, to spend a brief gay existence in the air, to lay its eggs, and then perish.

Family *Papilionidæ* (or Butterflies), otherwise called

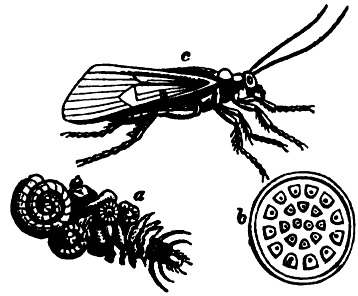
Diurna, are distinguished by the extraordinary beauty and variety of the colours which adorn their wings; and the number of species, each having some marked peculiarity, is enormously great. It is believed that not less than 2000 species exist in Britain alone. Beautiful as are many of these, there are still more splendid examples in other countries. Some of the foreign species exhibit an expanse of wing not less than nine inches; some display a metallic brilliancy of hue absolutely dazzling. The accompanying figure gives a good representation of the general aspect of the diurnal Lepidoptera.

Argynnis Paphia.

Family *Sphingidæ* (or Hawk Moths), otherwise called *Crepuscularia*, from their general habit of flying abroad in the twilight, live in much the same manner as butterflies. They are of a duller colour, and in flying make a loud humming noise. One species, noted for a skull-like patch of colouring on the back of the thorax, and thence called the Death's Head Moth, emits a squeaking kind of sound. In consequence of the peculiar aspect of its body, the sudden appearance of this insect has been popularly regarded as ominous of evil. It has a really formidable character towards bees, whose hives it enters boldly, scattering the inhabitants in alarm, and then preying upon the honey.

Family *Nocturna* (or Moths Proper) fly only by night, and are of a dull style of colouring. The most important tribe is that of the *Bombycidæ*, comprising the silk-worm and allied species. The silk-worm (*Bombyx mori*) is a native of China, where it has been domesticated for at least 3000 years. It was imported to Europe in the reign of the Emperor Justinian, 550 A.D. The caterpillar of the silk-worm, when it has attained its full growth—about three inches in length—proceeds to enclose itself in an oval-shaped ball or cocoon, preparatory to its assuming the state of the chrysalis or moth. The cocoon is formed by an exceedingly slender and long filament of fine yellow silk, emitted from the stomach of the insect. After emancipating itself from its silken prison, it seeks its mate. In two or three days afterwards, the female having deposited her eggs, from 300 to 400 in number, both insects terminate their existence.

The *Phryganea* is the type of a family, which some naturalists have placed as a distinct order, under the name of *Trichoptera;* while others assign it a place among the *Neuroptera*. The insects resemble the Lepidoptera in the distribution of the nerves of the wings, and the hairy covering with which both the wings and bodies are beset. The most remarkable peculiarity is seen in the larva state, when the creature —recognised as the Caddice-worm—resides in a cylindrical case, open at each end, to which they attach bits of stick, weeds, pebbles, or even small living shells, by the assistance of silken threads which they spin from their mouths. With the first three segments of the body protruded, they creep about with this case to feed, but withdrawing to the inside on the least alarm being given. When about to assume the pupa state, they fix their cases to some solid substance beneath the water,



Phryganea Grandis:
a, Larva in its case; *b*, Grating; *c*, Imago.

and close the two extremities with a kind of grating, so as to keep out everything but the water, which they require for respiration. Finally, in due time ascending to the air, they pass into the perfect state.

ORDER DIPTERA (or Two-winged Insects) are generally characterised by the peculiarity from which the name of the order is derived. The two wings correspond to the anterior pair in four-winged insects; besides which there are two short clubbed appendages, called balancers, which seem to be the rudiments of the posterior wings of other orders. Their mouth is formed for sucking, and their eyes are directed laterally.

Family *Culicidæ* (Gnats) are the most highly organised of all the Diptera; and the perfection of their suctorial apparatus, which is furnished with six lancets, many of us can attest from our individual experience of what is called the sting of a gnat. Their larvæ are aquatic, being those singular little red worms, thick at one extremity, which we frequently observe in stagnant waters. They move by a sort of jump, and are seen frequently resorting to the surface to imbibe a fresh supply of air. In their perfect state, they abound principally in the neighbourhood of water and marshy places. In Marshland, in Norfolk, the inhabitants are so annoyed by the gnats, that the higher classes, as in many hot climates, have recourse to a gauze-covering for their beds, to keep them off during the night.

Gnat.

The Mosquitoes are another species of the same family, which in many parts of the world interfere so much with our ease and comfort as to become one of the worst of pests, and a real misery of human life. They are very common in the woody and marshy parts of all hot countries; also abounding during their short summer throughout Norway, Lapland, and Finland. The Midge, so well known for its aërial dances, is the smallest species of the family.

Family *Tipulidæ* (or Water-spinners).—The most familiar species of the family is the *Harry Long-legs*. Many of the Tipulidæ in their larva state are very injurious to the roots of grass; others to the wheat-crops, by depositing their eggs in the centre of the corolla. They form a large tribe, subdivided by structure, but named from the places or substances they frequent: thus we have *Culiciform tipulæ*, *Terricole tipulæ*, *Gallicole tipulæ*, and *Floral tipulæ*.

Family *Tabanidæ* (or Gadflies) have highly organised mouths, the sucker being provided with six lancets. Many of them feed upon the blood of mammalia, and even of man himself. In the woods, in summer, they alight upon our face and hands, and put us to considerable pain. It is related that Messrs Kirby and Spence were frustrated in an entomological excursion by the prevalence of these insects, against the severe punctures of which they could find no protection. The Cleg (*T. pluvialis*) is the most common insect of the family.

Family *Œstridæ* (or Bot-flies) are all parasitic in some part of the body of mammalia. Most of them lay their eggs in the skins of animals, which they pierce for that purpose. This of course causes considerable pain, and the animals resort to many manœuvres to evade their tormentors. There are others, however, which deposit their eggs among the hair in situations where they can be licked off. These are swallowed, and hatched in the stomach, to the inner membrane of which the larvæ attach themselves, producing the disease termed the *bots* in horses.

Family *Muscidæ*, or Flies (*Musca*, a fly).—The most familiar species are the House-fly (*M. domestica*), and the Meat-fly (*M. vomitoria*). The first of these are great torments—not that they bite, sting, or hurt, but that they buzz, tease, and swarm on everything eatable. The larvæ are bred in manure and carrion, and undergo their change in a very few days. Their purpose in nature is to consume various substances which would otherwise taint the atmosphere.

They generally fly in the same manner as a bird, with the back upwards. They have, however, the wonderful faculty of reversing their position, and of flying backwards, as when starting from a window and alighting on the ceiling.

How the buzzing sound is produced by the fly, has given rise to various conjectures. Rennie ascribes it to the action of the air on the edges of the wings at their origin, as with an Æolian harp-string, or to the friction of some internal organ on the roots of the wing nervures.

Next, how does a fly feed? The sole instrument it possesses for eating or drinking is its trunk or sucker—an instrument convenient enough for liquid food. But having no grinders, how does it effect the consumption of solid matter, such as sugar? The microscope has solved the difficulty, and shewn that the fly dissolves its food by a fluid passing through the sucker, and converting the sugar into a sirup. Few flies withstand the severity of winter; but such as do, remain in a dormant state, frequently in haystacks.

The *Blow-flies* are well known. They deposit their eggs on meat; but when the larvæ which are produced from these are about to change into the pupa state, they penetrate into the earth. These flies are the pests of the larder.

Family *Hippoboscidæ* (or Horse-flies).—The young of this family are remarkable for undergoing their states of larva and chrysalis within the abdomen of the parent, and being born as matured pupæ. The Horse-fly (*H. equina*), the type of the family, infests the horse; strebla, the bat; ornithobia and ornithomya are found upon a variety of birds; leptotena, which has only rudimentary wings, inhabits the deer; and the mallophagi, which are destitute of wings, the sheep.

ORDER APTERA (Wingless Insects) includes a variety of creatures, most of which awaken unpleasant associations in our minds.

The family *Pulicidæ* (named from the *Pulex*, or Common Flea) have the rudiments of wings, but, in point of fact, depend for locomotion on the extraordinary elasticity of their legs, enabling them to make an enormous spring. The power of the flea to penetrate the human skin, and feed on the blood, is only too well known.

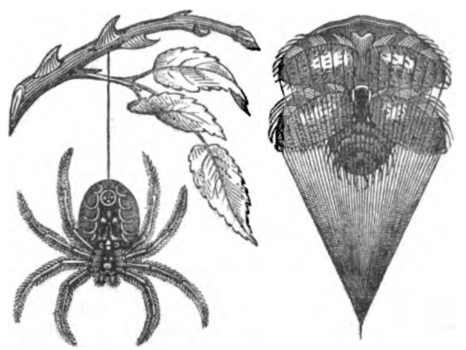
Family *Parasita* are typified by the common Louse, a creature justly regarded with loathing, because it never exists unless in connection with dirty habits. Man, the dog, sheep, and other animals, have each an appropriate parasite of this order. The Parasita are almost entirely destitute of eyes.

Family *Thysanoura* (or Spring-tails) are small insects possessing a forked tail for leaping. The *Podura villosa* is an example. Another is well known under the name of the *Sugar-louse*.

CLASS ARACHNIDA.

The Spiders and their allies, once considered as a branch of the Insecta, are now generally ranked as a distinct class. They may be defined as wingless, articulate animals, with jointed feet; the head confluent with the chest, and the body, consequently, consisting of only two segments. They have eight legs, and smooth or simple eyes. They possess no evident or distinct organ of hearing; yet it cannot be doubted that they have a perception of sound. A very acute sense of touch resides in their tarsi and palpi.

Their instincts are very perfect, and even capable of striking development; and they require the full exercise of these faculties to circumvent their prey—as the latter are instinctively apprehensive of their natural enemies. Many of them weave a net for the purpose of intercepting the flies on which they expect to feed; others, which have not the means of doing this, roam forth or form pitfalls, and exercise their ingenuity in a variety of ways to obtain their provisions. The thread of which the spiders make their nets is a substance similar to the silk of the silk-worm and other caterpillars, but of a much finer quality. It proceeds from reservoirs into which it is secreted in the form of a viscid gum, and issues from the hinder part of the abdomen, where the thread is drawn through little teat-like protuberances.



Spider, with thread-making organ magnified.

Nobody can have taken an early morning-walk, especially towards autumn, without having noticed the lines and webs of the spiders spread on hedge and fields. Spiders are oviparous, and their eggs are contained in a ball generally larger than the body of the parent, which is popularly known as the egg. Spiders undergo no metamorphoses.

ORDER PULMONARIA (*pulmo*, a lung) includes the Arachnidans, which breathe by means of pulmonary sacs or lungs, contained in the under side of the body, and opening externally by stigmata, or small apertures.

Family *Araneidæ* are divided into two sections—Terrestrial and Aquatic. The former, inhabiting the earth, are either suspended in the air or cavities in rocks or trees, or they are affixed to plants, or else they occupy holes in the ground. To this section belongs the *Mygale*, the most powerful insect of the order. When at rest, it covers a space of six or seven inches in diameter. Other species of Mygale burrow in the ground, and go under the name of *Mining Spiders*. They construct in dry situations subterranean cylindrical

galleries, often two feet deep, and so tortuous that the traces of them are lost. These they line with a silken tube, forming at its entrance a movable lid, composed of silk and earth, attached to the silken lining by a sort of hinge. As the spider goes out and in, this door shuts of itself. Thus the creature lives like a robber in a cave, ready at all times to make attack, and comparatively safe from detection.

The Aquatic Araneidæ dwell in the midst of the waters, in a cell filled with air; this consists of finely woven silk, in the form of a diving-bell, sometimes submerged, at others partly above the water, but always forming a dry and comfortable residence. From this their filaments are spread in the water to catch their prey.

Family *Phryneidæ* inhabit the intertropical regions of the Old and New World. Their habits are not well known; but they are much feared in the countries where they live. They are of a large size, and malignant aspect.

Family *Scorpionidæ* (Scorpions) are easily known by their large maxillary palpi, which form a prehensile organ resembling the claw of a lobster. In addition to these powerful instruments, they have, at the extremity of their long tail, a poisonous sting, which they employ with deadly effect. Seizing the little animal with the claws, they strike it with the sting, and then devour it. They are also fond of the eggs of spiders and insects. A small species inhabits this country; but it is between the tropics that the Scorpions attain their greatest development.

ORDER TRACHEARIA (τραχεῖα, the windpipe) includes such spiders as breathe by tracheæ.

Family *Solpugidæ*.—The spiders of this family are usually covered with long hairs or spines, and are said to be venomous. They frequent sandy districts of hot countries. They run with great rapidity, holding up their heads as if to defend themselves. Some minute species of this family, found in moss, are natives of our country.

Family *Phalangidæ* (φάλαγξ, a compact mass).—They are so called from the head, thorax, and abdomen being united. Their mandibles are very strong.

Family *Acaridæ* (Mites).—Arachnidans, which have either a single jointed pincer, representing an antenna, or a suctorious mouth. They are all extremely minute or even microscopic, but often present themselves to our view, running swiftly along damp furniture in dusky situations. They occur everywhere—beneath stones, in moss, under the bark of trees, in flour, and dried provisions; but nowhere are more conspicuous than in the recesses of old cheese, which they will devour to the crust, if not prevented. Others are parasites upon the skin or in the flesh of animals. Of the latter, the Itch insect is a remarkable example. They are naturally much flattened in form, but by suction become swelled out like blown bladders. Many persons consider the cheese acarus or mite a delicious morsel.

PROVINCE FOURTH.

VERTEBRATA.

The last and highest division of the Animal Kingdom is composed of animals in which the leading feature of distinction is the possession of a backbone or vertebral column. This peculiarity of structure is evidently designed, not merely as the central part of a framework giving support to the figure, but as a case for the preservation of a nervous system superior to that of other animals, the skull, which may be considered as an expansion of its upper extremity, containing a large nervous mass, named the brain, while a tube running along the interior of the vertebræ is occupied by the spinal-cord, a continuation, as it were, of the brain, and the trunk, from which nerves branch off to all parts of the body. The general bony fabric, of which the vertebral column is the main or central part, is *internal;* that is, the muscular masses of the body are extended over it—an arrangement, it will be observed, contrary to any in the lower provinces of creation, where the hard and sustaining parts of the frame are always *external.* The skeleton usually comprehends four extremities, serving for progression, and occasionally for prehension or seizing, but subject to many variations, according to the element in which the animal lives, and the nature of its necessities. By virtue of their superior nervous system, the vertebrated animals stand decidedly above other provinces in intelligence. Another notable peculiarity, is their possession of red blood.

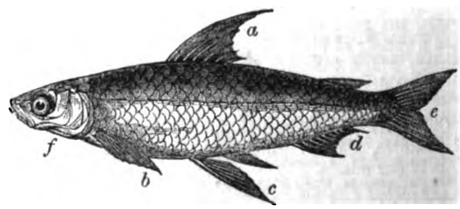
In the Vertebrata, there are four well-marked groups, denominated *classes*, rising in grades above each other, according to the character of their organisation, in this order: 1. Fishes; 2. Reptiles; 3. Birds; 4. Mammalia, or Suck-giving animals. The peculiarities on which the gradation is founded, will be adverted to in the introductory descriptions of the several classes.

CLASS FISHES.

The animals of this class are wholly aquatic, and are the only Vertebrata which, in their adult state, are formed for respiring beneath the surface of the water. They are furnished for this purpose with *branchiæ*, or gills—organs which we have already seen in the humbler provinces of the Animal Kingdom—being composed of a series of delicate filaments, through which the blood circulates, in order to be exposed to a needful chemical change by coming in contact with the air contained in the water. The lungs, by which the same function is performed in the higher vertebrata, do not exist in fishes; but in some a rudiment of this organ is found, in the form of a bag, serviceable in floating the animal, and called the *swimming-bladder*.

In fishes, the heart contains only two cavities; one of which receives the blood which returns from the system, the other propelling it through the gills, from which it is conveyed by the blood-vessels to the body at large. The blood in them, as in reptiles, is cold.

The individual vertebræ in the spinal column of the fish are hollowed on each side, with a bag of lubricating fluid between—an arrangement which gives great suppleness and agility of movement. In one large class, the bones never advance beyond a cartilaginous state. In the fishes generally, the limbs take the form of *fins*, the fore pair as what are called the *pectoral* fins, the hind pair as the *ventral* fins; and these are used rather as steering than as propelling organs. The chief progressive power resides in the vertically formed tail, which the fish uses exactly in the way in which we employ a single oar in sculling along a boat. The surface of the body of fishes is usually covered with scales; and these are sometimes quite bony, and fitted closely together, especially where the internal skeleton is soft. In many species the gills are covered by a corneous plate, styled the *operculum*.



Fish:
a, dorsal fin; *b*, pectoral fin of one side; *c*, ventral fins; *d*, anal fin; *e*, caudal fin, or tail; *f*, operculum.

Fishes are very generally carnivorous, preying much on the weaker of their own kind; but some are herbivorous.

They are nearly all oviparous (egg-producing), and some of them exhibit an amazing degree of productiveness. The cod is reckoned as having a progeny of four millions at a time! The female fish deposits her eggs, or spawn, leaving to the male the duty of afterwards impregnating them.

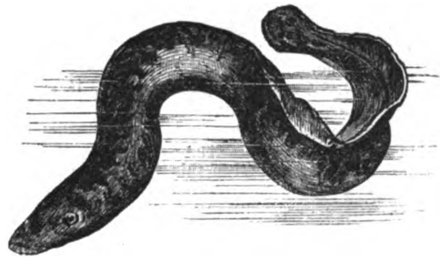
In the preceding representation of a fish, we see, 1*st*, the dorsal, anal, and caudal fins, prolongations of the spine, serviceable in balancing, steering, and progressing; 2*d*, the pectoral and ventral fins, four in number, answering to the four extremities of a quadruped, or the arms and legs of a human being, and likewise useful for motion. In most fishes, the ventral fins are placed far back, in the usual position of hind-legs; but in a few they are fixed far forwards, even anteriorly to the pectoral. These fins are composed of a set of bony or cartilaginous rays, answering to the bones of the hand and foot, and covered with a membrane. The bones representing the limbs are short and hidden under the flesh. Thus the chief movement of the fins is, as it were, at the wrist and ankle-joints. In some species, these fins are absent, and the fish is said to be *apodal*. In other instances, the pectoral fins are enormously developed, like the wings of birds, and even enable the animal to rise out of the water, and for a short time skim over its surface.

The teeth of fishes are chiefly designed to serve as means of seizing prey; they are ordinarily conical in form, sharp at the points, and curved backwards. They are not only placed on the jaws, but also on the tongue, the palate, and other parts of the passage into the stomach. In some species, the jaws and palate are furnished with hard enamelled plates, set together like a pavement, and fitted to bruise and break down the hardest substances capable of affording nourishment. In this way the *sparus* is enabled to browse upon the branching coral, for the sake of the animal matter which its cells protect. Fishes thus furnished were more abundant in the early ages of creation.

The first division of the Fishes is into *Cartilaginous* (gristly) and *Osseous* (bony). It is remarkable that the former alone existed at first and for many ages, and the osseous did not make their appearance till the era of the chalk-formation. The whole class is arranged in nine orders, of which three belong to the *Cartilaginous*, and six to the *Osseous*.

The Cartilaginous Fishes, equivalent to the *Chondropterygii* of Cuvier, are most prominently marked by that character of the skeleton from which they take their name. The different parts of this frame, moreover, which in the osseous fishes are united by distinct joints, here frequently form one continuous piece. This is most remarkable in the head, which is composed of a single piece; in which, however, the principal parts found in the bony fishes may be distinguished by various ridges, furrows, and holes. In respect of the skeleton, this division of the fishes ranks below the other; but, on the other hand, it comprises some of the fishes of greatest intelligence, and while the osseous are all oviparous, many of these are viviparous, bringing forth their young alive.

Order Cyclostomata derive their name from their round mouth, composed of a fleshy lip supported by a cartilaginous ring, and adapted for adhering to prey and drawing nourishment therefrom by suction. In this group of fishes, which is certainly the lowest of the whole class, the spinal column has no distinct division into vertebræ, but is merely a cylindrical membranous tube; the pectoral as well as ventral fins are absent; and the skin is soft and mucous, with scarcely a vestige of scales. This order contains but a single family. The *Lampreys* are the most allied to other fishes in their general organisation; they possess teeth within the ring, and with these they tear the bodies of the animals to which they attach themselves. There is a marine species two or three feet long, and other smaller ones which inhabit rivers. The *Myxine*, or Hag, is destitute of eyes, and is altogether of lower organisation than the lamprey; but



Lamprey.

the species that differs most in its general characters from the rest of the class, is the *Amphioxus*, or Lancelot. This is a very small animal, about an inch long, sometimes found lurking under stones in pools left by the ebbing tide. It is destitute of almost every one of the characters which have been mentioned as peculiar to vertebrated animals, and, nevertheless, can scarcely be classed anywhere else than with this family.

Order Selachii.—A peculiarity of the Cyclostomata, that of having the gills so attached to the skin that the water cannot escape from their intervals except by holes in the surface, is shared by this order; the two being accordingly recognised as *Chondropterygii branchiis fixis*.

This order comprises one family—that of *Sharks* and *Rays*. They are distinguished from other fishes by many peculiarities: in several species, the young are produced alive, the eggs being hatched within the body of the parent; and in others, the eggs are enclosed in a peculiar horny casing, which has often long tendril-like appendages, that coil around and attach them to other bodies. This is the case with the eggs of the common Dog-fish and Skate of our coast, and vulgarly known as *sea-purses*. The Sharks much resemble ordinary fishes in their form, having the gill-openings on the sides of the neck, and the eyes on the sides of the head, in both of which respects the Rays differ from them.

The White Shark is the most celebrated species of the tribe, being, from its size and voracity, the terror of mariners in the seas it inhabits. It frequents warm latitudes, but has occasionally visited the British shores. It has been known to attain a length of thirty feet, and the opening of the jaws in the largest individuals is sufficient to admit with ease the body of a man. The mouth is placed on the under surface of the head, from which circumstance the fish cannot bite whilst in the act of swimming forwards, so that a dexterous person has been known to defend himself from its attack. The teeth are triangular and lancet-shaped, with acute points and edges, and form several rows; they are not fixed in the jaw itself, but in a muscular membrane, by which they are erected and made to project when in use, lying flat in the intervals. As the foremost are torn away, they are replaced with others, which are brought up from the rows behind. So acute and strong are these teeth, that they are used by many savage nations as the armature of their weapons. The shark, possessed of this powerful apparatus for attack, and having a very hard and rough skin for defence, with very great muscular power, is a match for almost any of the inhabitants of the ocean. The Blue Shark, which frequents the Mediterranean, is not unfrequently a source of great trouble to the fishermen of our coasts, on account of the injury which it does to their nets, and the loss of the fish they contain. The Fox Shark, or Thresher, is another of the second-rate species which occasionally makes its appearance on British coasts; it is distinguished by the size of its tail, and the use it

makes of it as a weapon, both of offence and defence—whence its name.

A remarkable genus allied to the sharks is the *Zygæna*, or Hammer-headed Shark, so named from the projection of the head at each side in the form of a double-headed hammer, with an eye in the middle of each extremity. The *Pristis*, or Saw-fish, is another interesting genus. Its general form and character are like those of the sharks, but the snout is extended like the blade of a sword, with strong and cutting tooth-like spines on both edges. With this formidable weapon, the fish, which sometimes attains the length of from twelve to fifteen feet, will attack the largest whales, and inflict dreadful wounds. To the shark tribe also belongs the *Angel Fish* of our own coasts, which commonly grows to the length of seven or eight feet. Its appearance much belies its name, being, according to our ideas of beauty, one of the ugliest of fishes; but its flesh is by no means unpalatable.

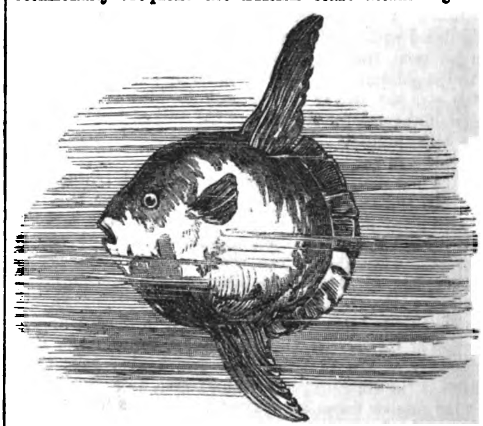
The *Rays* are less numerous than the sharks, and abound rather in temperate than in tropical seas. They are characterised by the extreme horizontal flattening of the body. The two sides are spread out horizontally, and unite with the expanded and fleshy pectoral fins to form one continuous surface. The eyes are placed on the back or upper surface, whilst the mouth, nostrils, and gill-openings, are below. To this group belong the Rays and Skates, Thornbacks, and other species; but the most interesting of all is the Torpedo, or Electric Ray, sometimes found on the Channel coast of England, but more abundantly in the Mediterranean. It possesses an electric apparatus, disposed in the space between the pectorals and the head and gills, and by which it can give a smart shock to any animal it touches. The flesh of the Rays is wholesome, and that of most species agreeable as food. The skin of some of them is employed in the arts for polishing, and from that of others shagreen is made.

Order Chondropterygii Branchiis Liberis, deriving their appellation from having the gills attached by one edge only, and hanging in fringes, as in the osseous fishes, form but one family—the *Sturiones*, or Sturgeon tribe. They are chiefly river-fish, and from their large size, vast numbers, and the quantity of food and other important products they afford, are extremely valuable to man. The common sturgeon of the British shores is about six feet long, and its flesh is somewhat like veal. The rivers falling into the Black and Caspian Seas, however, produce several other species, of which the largest not unfrequently attains the length of fifteen feet, one individual being recorded as having weighed 3000 pounds. The roe of the sturgeon furnishes the caviare, so much esteemed in Russia; and its air-bladder furnishes isinglass. The *Chimæra*—of which a northern species, known as the king of the herrings, often accompanies herring-shoals—is a genus intermediate between the sturgeon and the sharks, having the gills fixed, but having only one external gill-opening, covered by the rudiment of an operculum; this leads, however, to five interior passages.

The Osseous Fishes are classified by Cuvier with a reference chiefly to characters of the fins and gills. Three orders are denominated *Malacopterygii*, as having the fin-rays soft, each bearing an additional designation according to the position or absence of the ventral fins. One order is designated as *Acanthopterygii*, from having the fin-rays spiny. Two other orders are distinguished by other peculiarities—*Lophobranchii*, or Tuft-gilled, and *Plectognathi*, or Jaw-soldered.

Order Plectognathi approaches the Cartiligines in many points of organisation; principally, however, in the slow ossification of the skeleton, and the imperfect structure of the mouth. They derive their name from the union of the upper jaw to the skull; so that its motion is obtained, not from a distinct joint, but by the mere flexibility of the half-ossified cartilages. The gill-lid is concealed under the thick skin, with only a small opening; the ribs are scarcely developed; and there are no true ventral fins. This order contains two families.

The *Gymnodontes* (Naked-toothed Fishes) are distinguished by having the jaws covered with a substance resembling ivory, arranged in small plates—which are reproduced as soon as destroyed by use—and really representing united teeth. They live on crustacea and sea-weed, and their flesh is not palatable. Some species are reputed to be poisonous, at least at particular seasons. The most remarkable species of this family are the spinous globe-fishes, *Diodon* and *Tetraodon*—their technical names being derived from the apparent division of their jaws into two and four tooth-like pieces respectively—which have the power of blowing themselves up like balloons, by filling with air a large sac which nearly surrounds the abdomen. When thus inflated, they roll over with the belly upwards, and lose all power of directing their course; but they are remarkably defended by spines over their whole surface, which are erected as they are inflated. They are mostly inhabitants of warm seas, but a specimen is occasionally drifted to our coasts. The *Sun-fish* has a body of somewhat similar form, but incapable of inflation; from the shortness of the tail, it looks like the anterior half of a fish cut in two in the middle. Some species which occasionally frequent the British coast attain a great



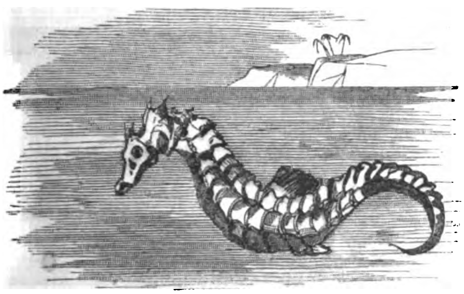
Sun-fish.

size, having been known to weigh 300 pounds, while others are much larger.

The second family, *Sclerodermi*, contains fishes which are remarkable for their very hard and granulated skins. They have a prolonged muzzle, with distinct teeth. Their skin is covered with scales in some species, and in others very rough, like a file, whence they are commonly termed *file-fishes*. They are principally inhabitants of warm seas, living near rocks, or on the surface of the water, their brilliant colours sparkling in the sunshine. The *Balistes*, or File-fishes, are generally remarkable for the appendages of various kinds attached to the surface of the body. One of the most curious species in this respect is the *B. pencilligerus*, whose body is covered with little branched stalks resembling aquatic plants. Not improbably, these may serve as lures for the animals upon which this fish preys, its body lying concealed among the rocks, whilst these curious little prolongations are gently agitated by the water.

Order Lophobranchii is a very small one, containing but one family, of which the genera are few. Their appearance is very peculiar. The tufted gills are covered

by a large operculum; but this is bound down by membranes on all sides, so that there is only one small hole for the water to escape. The body is covered, not with small scales, but with shields or plates, which often give it an angular form. In general, they are of small size, and almost without flesh. The *Syngnathus* possesses a long tubular snout. It is peculiar for the protection it affords to its young, which resembles that provided in the marsupial mammalia. The eggs are conveyed into a sort of pouch under the body of the male, and are hatched there, the young fry afterwards finding their way out. Some of these are found in the British seas; as are also the *Hippocampi*, commonly called *sea-horses*,

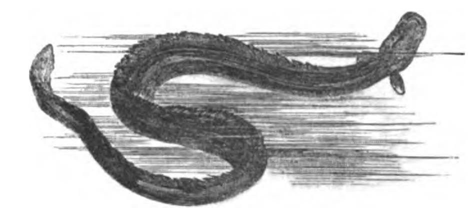


Sea-horse.

from the resemblance of the upper part of the body (especially when the dead specimen bends in drying) to the head and neck of a horse in miniature. The tail is prehensile, and they climb or hold on to the stalks of marine plants by its means.

ORDER MALACOPTERYGII APODA (Soft-finned Fishes, destitute of ventral fins) form but one natural family—the *Murænidæ*, or Eel tribe. They are all lengthened in form, have the spine extremely flexible, the skin thick and soft, and the scales almost invisible. Many of them inhabit rivers, whilst others are exclusively marine. The eel is, strictly speaking, a fresh-water fish; but when living in rivers, or other collections of water communicating with the sea, it migrates towards the ocean in the autumn. During the winter, they bury themselves in the mud; and in the spring, those which have migrated usually return up the rivers, together with the young fry produced from the spawn, the number of which is enormous. Like trout, eels are much affected in appearance and quality by the waters they inhabit. They are very voracious, especially during the spring and summer months, not only devouring insects and small fry—on which last account they are often excluded from fish-ponds—but also attacking larger fish. As is well known, the eel can live for a little while out of the water, and is often found wriggling its way by night among damp grass, in pursuit of frogs, slugs, and other prey. It is enabled to do so by the smallness of the gill apertures, keeping the breathing organ moist—the only requisite, it appears, for prolonging the life of a fish out of its ordinary element. Occasionally they eat vegetable substances. By means of a long and capacious air-bladder, eels rise to various elevations in the water with great ease.

The Conger is a marine eel, frequenting the European seas; it is one of the largest of the family, being from four to six feet long, and as thick as a man's leg. The *Muræna* is destitute of pectorals as well as ventrals: one species of it was much esteemed by the ancients, who carefully fed it in ponds; and it is recorded that offending slaves were sometimes flung alive into the ponds for their supply. The *Gymnotus*, or Electric Eel, is a native of the South American rivers. It attains the length of five or six feet, and communicates shocks so powerful that men and horses have been stunned by them. This power seems voluntary, and can be sent in a particular direction, or even through the water, the fish in which are killed or stunned by its shocks. By giving these the animal is greatly exhausted, and requires rest and



Electric Eel.

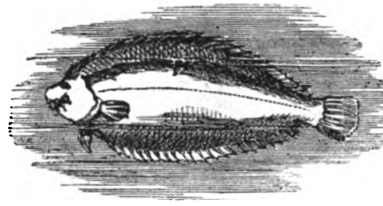
nourishment before it can renew them. The electric organ extends along the under side of the tail, occupying about half its thickness. It consists of parallel layers of membrane, joined by numerous transverse folds, so that a number of canals or cells are formed which are filled with gelatinous matter. The apparatus is largely supplied with nerves. Some species of this family, which is commonly known under the name of *Anguilliform*, or Eel-like Fishes, approach very closely to the lower reptiles in the structure of the air-bladder or lung; and in these the external opening of the gills is usually very small.

ORDER MALACOPTERYGII SUB-BRACHIATA derive their subordinate name from having the ventral fins brought forwards beneath, or even in advance of the pectoral. They form three families.

Family *Gadidæ* (the Cod tribe) are easily known by the softness of all their fins, and by having the ventrals inserted under the throat, and pointed. The Cod is nearly the largest of the family, but is usually surpassed by the ling, which is commonly from three to four feet long: both these are especially valuable for their palatableness when salted. The Haddock is a smaller species, nearly allied to the cod; for eating in the fresh state it is perhaps the most delicate of the whole family. Many other species are useful to man, occurring in large numbers in particular localities. Such are the Whiting, the Coal-fish, the Pollock, the Haak (of which some species frequent high southern latitudes), the Burbot, or Eel-pout (which ascends rivers), the Rockling, and many others. Besides their use as food, these fish are valuable on account of the oil obtained from their large livers, which is very serviceable in the arts and in medicine.

The second family is that of *Pleuronectidæ* (the Flat-fish, or Flounder tribe).—The form of these fish is peculiar, not only for the extreme flattening of the body, but for its deficiency in symmetry. The two flat surfaces —one of which, in the ordinary position of the fish during life, is above, and the other below—are in reality the two *sides* of the fish, differing in several important respects. Both the eyes are placed on the upper side; and its colour is usually much deeper than the other. The body, from the head backwards, partakes a little of the same peculiarity. The two sides of the mouth are not equal, and the pectoral fins rarely so. On the other hand, the dorsal fin, which runs along one of the lateral edges, corresponds with the anal, which occupies the other, and with which the ventrals are sometimes united; so that, when we look at the fish in its usual position, its body appears more symmetrical than it really is. These fishes are destitute of air-bladders, and they frequent the bottom of the sea, from which they seldom rise. The colour of their upper surface usually corresponds closely with that of the ground on which they lie, and thus they escape the observation of their enemies, and are unnoticed by the small fishes on which they prey. Individuals are occasionally found, however, in which both sides are alike; these are called *doubles:* it is usually the dark side which is doubled. The fishes of this family are found along the shores of almost all countries, and are, generally speaking, wholesome and

agreeable as food. The form and aspect of the different species exhibit little variation. The Flounder, Turbot, Brill, Plaice, Dab, and Sole are the chief species of our



Sole.

own coasts. The Halibut is a very large species, sometimes attaining the length of six or seven feet—frequently taken in the British seas. Other species inhabit the Mediterranean.

The *Discoboli*, so named from having their ventral fins formed into a sucker or disk, are the last family of this order. By this curious provision, the fish have the power of attaching themselves to rocks and other hard substances, and thus to remain and find their food in situations where every other species would be swept away by the current of water. Several species are found on the British coasts, but they are mostly small; the most considerable is the Lump-fish, which is occasionally eaten. The *Echeneis remora*, or common Sucking-fish, is placed under this family, but probably ought to constitute a distinct group, since its disk is not formed by the ventral fins, but by a series of thin and movable cartilaginous plates fixed to the head, by means of which the animal can attach itself to any kind of surface. It seems to prefer bodies in motion; and is not unfrequently found adhering to larger fish, and to the bottoms of vessels, whose course it was once absurdly believed capable of arresting. It is abundant in the Mediterranean.

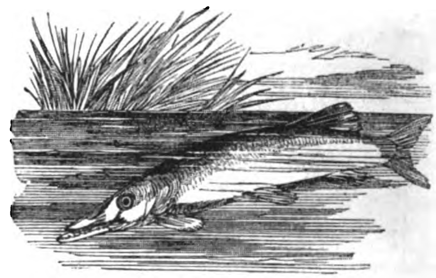
ORDER MALACOPTERYGII ABDOMINALES consists of soft-finned fishes, having the ventrals attached to the abdomen, behind the pectorals. It is a very numerous order, including the greater number of the fresh-water fishes. There are five families.

Family *Cyprinidæ* (Carp tribe) are all fresh-water

Carp.

fishes. They have the mouth shallow, the jaws feeble, and very often without teeth; but the pharynx is strongly toothed. They are among the least carnivorous of fishes, feeding chiefly on seeds, the roots of plants, and decomposing vegetable matter. The common Carp is imported into England from the warmer parts of Europe; it thrives better in ponds or lakes than in rivers; it feeds on insects and worms, as well as on vegetables; and it is very tenacious of life, so that it is easily transported from place to place. The Barbel is an allied species of considerable size, sometimes growing to the length of three feet. It frequents the sluggish parts of the Thames and its tributaries, and is said to plough up the mud with its nose, which, setting various minute animals adrift in the water, attracts the small fishes on which it feeds. The Cobitis or Loche is another British species, which is interesting in some of its habits. It inhabits the mud of stagnant waters, and can subsist a long time after the water has been dried up or covered with ice. The Anableps, a genus allied to the cobitis, has a remarkable peculiarity of structure in the eye, each cornea and iris being divided by transverse bands, so as to give the fish the appearance of having four eyes. The object of this conformation is unknown. The fish inhabits the rivers of Guiana.

The *Esocidæ* (Pike tribe), the most voracious of the



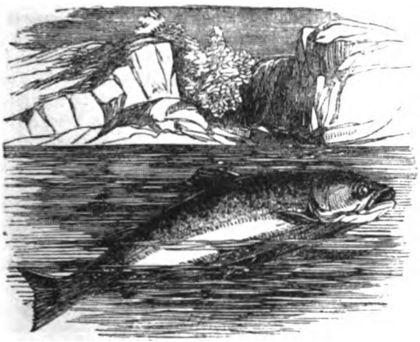
Pike.

fresh-water fishes, are distinguished by the absence of fatty matter in the dorsal fin (which exists in the salmon tribe), and by the position of this opposite to the anal fin. The Pike is very destructive to the smaller fishes in the ponds and rivers in which it exists, and occasionally attains a considerable size, weighing sometimes thirty or forty pounds. The *Gar-fish*, or Sea-pike, is an allied species, frequenting the British shores, and stretching into the Arctic regions. Some of this kind have been known to attain the length of eight feet, and to bite very severely; hence they may be considered as the sharks of northern seas. The *Mackerel-pike*, or *Saury*, is another British fish of this family; it is gregarious in its habits, and is followed and preyed upon by porpoises, tunnies, and other large fish. To this family belongs the most common of the flying-fish, though it is not the only one which deserves the title.

The *Siluridæ* are distinguished from all the rest of the order by the want of true scales; having only a naked skin, or large bony plates. The fishes of the genus *Silurus* inhabit the rivers of warm countries; they have a strong spine in front of the dorsal fin, which can be laid flat on the shoulder, or perpendicularly erected so as to become a formidable weapon; and the ragged wounds inflicted by it are reputed (but probably erroneously) to be poisonous. One species, belonging to the sub-genus *Malapterurus*, an inhabitant of the Nile and of the rivers of Central Africa, has electric properties, similar to those of the torpedo and gymnotus.

The *Salmonidæ* (Salmons and Trouts) are very extensively, indeed almost universally, diffused over the globe; some of them being confined to fresh water, and others passing a part of their lives in the sea, but resorting to rivers to deposit their eggs. They are distinguished by the fatty deposition in the dorsal fin, from part of which the spines often disappear. All of this family are clouded with dusky patches when young, and many remain permanently spotted. The flesh of most of them is esteemed as food. The Salmon inhabits the seas of comparatively cold regions, ascending the rivers for the purpose of spawning, at seasons varying with the climate. The efforts which they make to overcome difficulties in the ascent are very great: they will not only swim against powerful streams, but will leap up cascades of considerable elevation, and find their way to the brooks

and small lakes of lofty mountains. After this operation is accomplished, they return to the sea, followed by the young fish. These, in their turn, ascend the rivers for the same purpose, and are understood to resort to those in which they were produced. The Trout appears to vary much in size and colour, according to the climate and other conditions of its residence, so that it is difficult to distinguish species from mere varieties. The growth of this fish is wonderfully rapid, individuals previously marked having been found, when recaptured three weeks



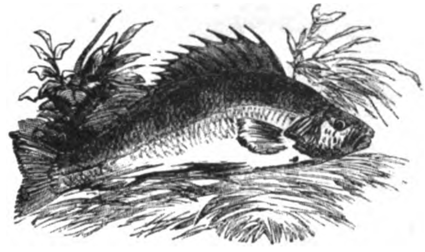
Salmon.

afterwards, to have grown several pounds heavier. Besides these may be mentioned, as belonging to the same family, the *Smelt*, which is sometimes found abundantly, but locally, in the estuaries of British rivers; and the *Capelin*, which is employed on the shores of Newfoundland as a bait for cod, and is sometimes taken in such quantities as to serve as manure for the land.

The *Clupeidæ* (Herring tribe) is one of the most important families in the whole class, for the amount of food it supplies to man. The fishes belonging to it resemble the Salmonidæ in many characters, but differ in having no fatty matter in the dorsal fin. They chiefly inhabit the seas of the temperate zone. The Herring, which periodically visits our shores in such immense shoals, was formerly supposed to migrate from the Arctic seas; but this is now ascertained to be a mistake, the fish being almost unknown there, and often appearing on the southern coast of Britain before the northern. The fact is rather that the herring, like the mackerel and many other fish, usually lives in the open ocean, and resorts to the nearest coast to deposit its spawn. There are many well-known species, differing but little from the herring, which frequent separate localities. Thus, the *Pilchard* is caught especially on the coast of Cornwall, and other shores to the southward of those on which the herring most abounds. The *Sardine* is taken on the west coast of France, and in the Mediterranean, where the herring never appears. The *Sprat, Whitebait, Shad*, and other British species, belong to the same family, as does also the *Anchovy*, abundant in the Mediterranean, and well known for its rich and peculiar flavour. Other species inhabit the American, African, and Indian seas and rivers, but are less abundant than those already mentioned.

Order Acanthopterygii (Spiny-finned Fishes) are divided by Cuvier into fifteen families.

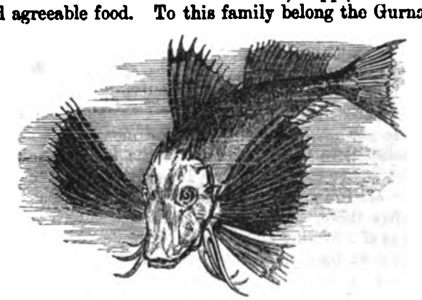
Percidæ (the Perch tribe).—These are very numerous in the waters of all warm climates, some species inhabiting the rivers, and others the open sea. Their bodies are oblong, and covered with hard or rough scales; and the gill-covers are toothed at the margin. They are mostly *thoracic*, or have the ventral fins under the pectoral. Some, however, are *jugular*—that is, have the ventral fins placed upon the throat, further forwards than the pectorals; and some are *abdominal*. Their teeth are very minute, and set close together in numerous rows. The flesh is, in general, agreeable and wholesome. This family, of which some species are found in almost all the rivers in the world, includes all the fish known as perches, and a large number of marine



Perch.

fishes used as food on different shores. Some of the most remarkable are—the *Trachinus*, or Weaver, which has a very prolonged and sharp dorsal spine, capable of inflicting a severe injury, and which fishermen believe, but erroneously, to have poisonous properties; the *Uranoscopus*, or Star-gazer—so called from the position of the eyes upon the top of a nearly cubical head—which lies concealed in the mud, and attracts its prey by a filament protruding from its mouth, and serving as a bait to small fishes; the *Polynemus* (many fillets), whose pectoral fins are prolonged on each side into threads twice as long as the body, and of which a species inhabiting the Ganges, termed the Mango-fish, is esteemed the most delicious in India; the *Sphyræna*, or Sea-pike, to be distinguished from the common pike, of which one tropical species, the *Barracuda*, is much dreaded for its size and voracity; the *Red Mullets*, or, more properly, *Surmullets*, of the British seas; and many others.

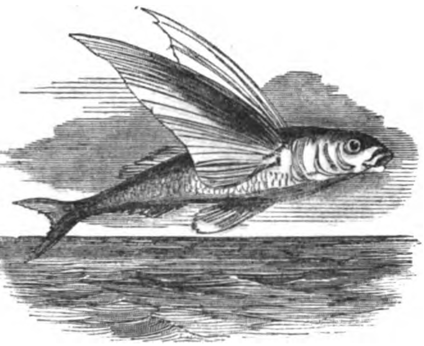
Triglidæ (the Gurnard tribe).—These bear a general resemblance to the perches, but have the head peculiarly armed with spines or hard scaly plates. In several species the pectoral fins are very much extended; but in none, except the flying-fish, are they sufficiently powerful to raise the animal out of the water. Many species of this tribe are found in the temperate seas, which, though inferior in flavour to the surmullets, supply wholesome and agreeable food. To this family belong the Gurnards



Gurnard.

and Sticklebacks of our own coast; the *Scorpæna*, a gregarious fish, living among the rocks; the *Sebastes*, or Norway haddock, rather a large species, the spines of which are used by the Greenlanders as needles; and a large number of others. The most interesting of all is the *Dactylopterus*, or Flying-fish. This has a kind of supplementary pectoral fin on each side, formed of a membrane stretched over finger-like processes, which in the gurnards are unconnected. By the impulse of these on the surface of the water, the flying-fish can rise several feet into the air, and suspend themselves above the surface for a few seconds, often skimming lightly over it for a considerable distance. They are gregarious; and it is when a shoal of them is chased by the Coryphæna

—commonly, but erroneously, termed *dolphin*—or some similar enemy, that the most remarkable leaps are taken.



Flying-fish.

They sometimes fall victims to predaceous birds, and not unfrequently fall upon the deck of vessels that happen to be passing amongst them. The finger-like processes are usually prolonged beyond the fins, and appear to possess an amount of sensibility unusual in such parts.

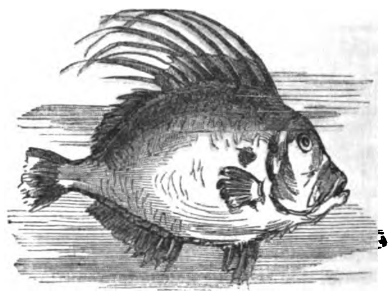
The *Sciænidæ* (Maigre family) have a general resemblance to the perches, but differ from them in the absence of teeth from the palate, and some other particulars. They principally belong to tropical seas, a few inhabiting the Mediterranean.

The *Sparidæ* (Sea-bream tribe) resemble the last in general form, but have no spines on the gill-covers. Some of these, including the genus Sparus, already mentioned as grinding down the stony corals, have the sides of the jaws covered with round flat teeth, resembling a pavement. Others have teeth with cutting edges.

Another small family, *Menidæ*, differs from the last chiefly in the great extensibility of the upper jaw.

The next family, *Squamipennes*, is so named because the soft and even the spinous parts of their dorsal fins are so covered with scales as not to be distinguished from the rest of their bodies. The most interesting genus is the *Chætodon*, of which several species, remarkable for the beauty of their colours, abound in tropical seas. One of these, the *C. rostratus*, which has a very prolonged snout, has the faculty of shooting insects with drops of water projected from the mouth, and it then seizes them as they fall. This power is the more extraordinary, as, according to the laws of the refraction of light, the place of the insect will appear to the fish different from the reality—the rays passing from a rarer to a denser medium; and the drop must not, therefore, be projected in the line in which the insect *appears* to be, but somewhat below it. This little fish, which is a native of India, is often kept in glass-vases by the residents there, as gold-fish are in this country, for the purpose of affording amusement by its dexterity.

The next family, *Scomberidæ* (the Mackerel tribe) is one of very great importance to man. It comprises a large number of genera, a vast collection of species, and numberless individuals. The aspect of the common Mackerel, with its spindle-shaped, beautifully coloured, smooth, and small-scaled body, is well known. It very rapidly dies out of water, and soon becomes tainted. The Mackerel has been supposed to be a migratory fish, on account of its appearing on our shores in immense shoals at particular epochs. But it may be caught all the year round on our coasts, which shews that it does not wholly desert them, as is done by the really migrating tribes. The fact is, that it passes most of the year in the open sea, and that its object in approaching the shore is to deposit its spawn; after which, those that have escaped being entrapped by the ingenuity of man, return to their former quarters. The extent and importance of the mackerel-fishery of Britain, especially in the south and east, are well known. The Tunny is an allied species attaining a much greater size, and also valuable as an article of food. It frequents the Mediterranean, and is occasionally seen on our own shores. It sometimes attains the length of fifteen or even eighteen feet. To this order belongs also the *Xiphias*, or Sword-fish, distinguished by its long pointed beak. This is a most powerful offensive weapon, and with it this fish attacks the largest inhabitants of the ocean. By its high dorsal fin and expanded tail, it is able to impel itself forwards with great force; and when attacking a large animal, it makes a violent dart against it, quite transfixing it with its sword. It has been known in this manner to drive its beak into the timbers of a ship, and, not being able to withdraw it, to break it off and leave it. The sword-fish abounds in the Mediterranean, but is less frequent in the Atlantic. It is very palatable as food, and often attains the length of fifteen feet. The *Dory*, of which



Dory.

one species is highly prized by epicures, is another fish of the same family. It is remarkable for the filamentary prolongations from its dorsal fins. And, lastly, may be mentioned the *Coryphæna*, commonly known as the Dolphin. This is a large and splendidly coloured fish, which darts through the water like a radiant meteor, exhibiting an extraordinary play of colours when brilliantly illuminated. It has long been celebrated for its change of colour when dying; a peculiarity which belongs to many other kinds of fish. It swims with great rapidity, and is very voracious, committing great havoc among the flying-fish and others of like size. The influence of light on the colour of animals is remarkably shewn in the far superior brightness of the Indian Scomberidæ, when contrasted with the blackish hue of those of the northern seas.

The family of *Tænidæ* (Ribbon-shaped Fishes) is a small one allied to the Scomberidæ, differing chiefly from it in the remarkable lateral flattening of the body. Few species are known on our shores; one of the largest, *Lepidopus argyreus*, the Scabbard-fish, occasionally appears on these coasts; it is about five feet long, swims with extreme rapidity, and often with the head above water. Allied to this is the *Trichiurus*, some Indian species of which have been said to possess electric properties; but this is doubtful.

The *Theutyes* (Lancet-fish tribe) are another small family allied to the mackerels, but are peculiar for their cutting spines on each side of the tail, and a horizontal spine before the dorsal fin. They have only a single row of teeth, and feed chiefly on marine plants. Their powerful lancet-shaped spines are used very dexterously as weapons of defence; and in this respect may be compared to the horns of the Ruminantia.

The fishes of the tenth family, *Pharyngina labyrinthuformæ*, are characterised by a very peculiar structure, from which they derive their designation. The membranes of the pharynx, or back of the mouth, are divided into small irregular leaves, containing cells among them, which the fish can at pleasure fill with water; and by ejecting a portion of this water the gills are moistened, thus enabling it to continue respiration out of its proper

element. By means of this apparatus, which resembles that possessed by the land-crabs, these fishes are enabled to quit the pool or rivulet which constitutes their usual element, and move to a considerable distance over land. Such a provision is especially desirable in tropical climates, where shallow lakes are often dried up by a continued drought, and their inhabitants must perish if not enabled to migrate. The people of India, often witnessing the appearance of these fishes where they had no previous existence, believe that they fall from heaven. Some of them are able not only to traverse plain grounds, but can climb steep banks, or even trees, in the course of their journeys. The most curious is the *Anabas*, commonly known as the Climbing-perch of Tranquebar, which climbs bushes and trees in search of its prey.

The *Mugilidæ* (Mullet tribe) are lengthened and often nearly cylindrical fishes, with a somewhat projecting snout, and a very small mouth placed beneath it. They are gregarious in their habits, frequenting the mouths of rivers in large troops, and constantly leaping up out of the water. There are several species found in European seas, which are much esteemed from their rare delicacy. That best known on the British coast is the *Mugil chelo*, or Thick-lipped Gray Mullet, sometimes called the Sea-woodcock. The fishes of this family feed in part upon crabs and other small crustacea.

The members of the family *Gobiodæ* (or Goby tribe) are known by the thinness and flexibility of their dorsal spines. Many of them are remarkable for producing their young alive, the eggs being hatched within the body of the parent. This is the case with the Blenny, of which several species frequent the British shores, living in small troops among the rocks. They are remarkably tenacious of life, and are capable of being kept a good many days in moist grass or moss, but they are of little value as an article of food. One of the most interesting species of this family is the *Anarrichas lupus*, or Sea-wolf. It inhabits the northern seas, and is often met with on our shores, attaining the length of six or seven feet. It is very formidable in aspect, and the size of its teeth, with the colours and peculiar physiognomy of its head, remind the observer of the carnivorous mammalia. Its manners accord with its aspect, for it is remarkably strong, very active, and equally ready to defend itself or to attack an enemy. It often enters the fishermen's nets, for the purpose of plundering them of the entangled fish; and when the fishermen attack it, and it cannot escape, it fights like a lion. The Arctic seas appear to be its appropriate home, and there it attains a larger size than further south; it is very valuable to the Icelanders, who salt its flesh for food, and employ its skin as shagreen. The true Gobies have the ventral fins placed far forwards, and united at their bases; they are chiefly remarkable for the *nest* which they construct among the sea-weed for the protection of their young. They prefer a clayey bottom, in which they excavate canals, and in these they pass the winter.

The next family, *Pectorales pedunculati*, derives its name from the peculiar structure of the pectoral fins, which have a kind of wrist formed by the elongation of the bones to which they are attached. This conformation gives these fishes a very strange appearance, and enables them to leap suddenly from the water in pursuit of their prey, and even to leap over the sand. In many of them the skeleton is semi-cartilaginous. One of the most curious is the *Lophius*, or Fishing-frog, of the British seas, which is met with chiefly on muddy shores. It derives its name in part from its wide gaping mouth, and in part from the peculiar manner in which it angles for its prey. There are some curious appendages to its head, which terminate in long, round, and rather brilliant filaments, having a resemblance to worms. The animal lurks in the mud, and puts these appendages in vibration; they are mistaken for worms by small fishes, which they attract, and these are gulped down the capacious maw of the lophius. To such an extent is this voracity carried, that the *angler* (as it is sometimes called) is often an article of value for the fish which it has in its stomach, although its own flesh is but little worth! There is an allied genus, the *Chironectes*, a species of which abounds on the north coast of Australia. When the tide ebbs far back in the dry season, these frog-fishes are so abundant, and capable of taking such vigorous leaps, that persons visiting these places have mistaken them at first sight for birds. The fishes of this genus can inflate their large stomachs with air, in the manner of the tetraodons.

The *Labridæ* (Wrasse, or Rock-fish tribe) are easily known by the thickness and fleshiness of their lips, whence their name. Those of the genus *Labrus* are known on the British shores by the name of *old wives;* some of them vary considerably in colour. They frequent deep pools among the rocks, hiding themselves in sea-weed, and feeding mostly upon crustacea. This family contains a large number of species, chiefly inhabiting tropical seas, and remarkable for the beauty of their colours, but they are usually of small or moderate size; their habits are little known, and they are of but slight direct importance to man. Some of them have received the name of *parrot-fishes*, on account of the brilliancy of their markings and the form of their jaws.

The last family of the Acanthopterygii consists of the *Fistularidæ* (Pipe-mouthed Fishes), at once recognised by the very prolonged muzzle. The body, too, in some species is long and cylindrical, whilst in others it is oval and compressed. They are chiefly found in warm latitudes; but one species, *Centriscus scolopax*, Sea-snipe, Sea-trumpet, or Bellows-fish, is occasionally found on the Cornish coast, as a straggler from the Mediterranean.

CLASS REPTILES.

The class of vertebrated animals next above fishes is distinguished by a name expressing *creeping habits* (*repo*, I creep). Like fishes, the animals of this class are oviparous, or produced by eggs, and many of them are covered with plates and scales. They are also, like fishes, cold blooded. They are superior, however, to fishes, in having lungs, and breathing the atmosphere. While the fish possesses a heart of only *two* cavities, that of the reptile consists of *three*, which may be considered as, in one sense, an imperfect form of the organ; and the consequence is, that only a portion of the blood, on returning from the veins, is propelled through the lungs, the greater part passing again into the circulation without being aërated. Hence it is that the blood is cold, and the digestive powers sluggish and weak. The vitality of the reptile may be said to be low, and it is not surprising that many of them are capable, under a low temperature, of falling into a state of torpor, during which the whole of the animal functions are suspended.

There are differences among naturalists as to the classification of Reptiles; but latterly the tendency has been to consider the Tortoise, the Lizard, the Serpent, and the Frog as the four leading types; and, accordingly, the whole may be ranked in four orders—*Chelonia*, *Sauria*, *Ophidia*, and *Batrachia*.

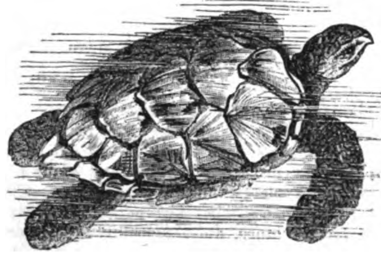
Order Chelonia are distinguished by a peculiar form of the skeleton, having evidently in view the protection of the animal. In typical species, the ribs are expanded so as to form but one bony plate, having no flesh outside, but covered with horny plates, secreted from the skin like hair or nails; the breastbone being similarly expanded into a plate, covering the whole of the lower surface, and joining the edges of the upper plate; so that the animal may be said to be sheltered in a box formed of its bones. Within this box, the upper plate of which is named the *carapace*, and the lower the *plastron*, the animal can even withdraw its head and feet, and thus set most enemies at defiance. When it is

observed that the Chelonia are in general without teeth, claws, or other sharp instruments, and are for the most part herbivorous and of gentle dispositions, it seems not inappropriate that they should be provided with such a means of defence.

In the Chelonia, the jaws are covered with a horny substance, resembling that of the bills of birds; but their surfaces are usually rounded, so as to be more adapted to bruise than to bite. In those designed to live in the water, the extremities take the form of paddles.

The family *Chelonidæ* (Turtles) are designed for a sea-life, feeding chiefly on marine-plants, and only coming on land to deposit their eggs, which they do thrice a year, laying about a hundred at a time. They are generally large animals, sometimes exceeding five feet in length, and 800 pounds in weight. The bones and plates are not so closely joined as in land-tortoises; consequently, their bodies possess a certain degree of flexibility. The *Chelone midas* (Green, or Edible Turtle) is noted for the delicious food which it yields. Animals of this species may be seen in the tropical seas of America, browsing in large flocks on the plants growing on the bottom, only ascending to the surface now and then to breathe. They migrate hundreds of leagues to lonely shores, where there are loose sands fitted to hatch their eggs. Ascension Island, in the South Atlantic Ocean, is noted as one of their favourite retreats.

The *Chelone imbricata* (Hawk's-bill Turtle) is a smaller species, having a horny and pointed muzzle,



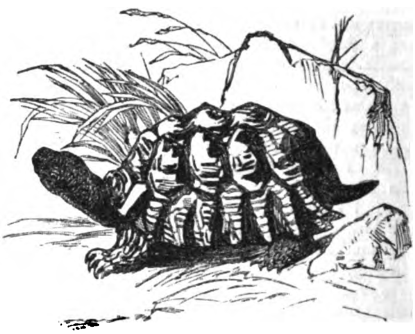
The Hawk's-bill Turtle.

fitted to cut as well as bruise. It is remarkable on account of the horny plates covering its carapace, which, being thicker and stronger than usual, and beautifully coloured, furnishes a material for combs and other useful articles. About twelve pounds of *tortoise-shell*, as the substance is called, is yielded by each full-grown animal. These plates do not join at the edges, like those of land-tortoises, but overlap each other, like the scales of other reptiles.

The *Chelone caretta* (Loggerhead Turtle) has a strong mouth with sharp jaws, and feeds upon various marine animals, as well as plants. The carapace is covered, not by plates, but by a thick leathery skin. This animal (called also Sphargis) inhabits the Mediterranean, as well as the Atlantic and Pacific Oceans.

The family *Emydæ* (Fresh-water Turtles, or Mud Tortoises) are comparatively small animals, distinguished by the form of their feet, which end in toes furnished with claws, but nevertheless, being webbed, are useful for swimming. They inhabit the rivers of the south and east of Europe. To this group belongs the *Snapping Turtle* of America, a comparatively destructive and powerful animal, possessed of sharp claws and a long tail, and capable of biting through a stick half an inch in diameter. It lives either upon small marine or land animals.

The family *Testudinidæ* (Land Tortoises) have their armour thicker and stronger, in proportion to their size, than the aquatic species. The legs are short, and the feet clubby, shaped somewhat like those of the elephant, and adapted for walking on firm ground only, as the



Tortoise.

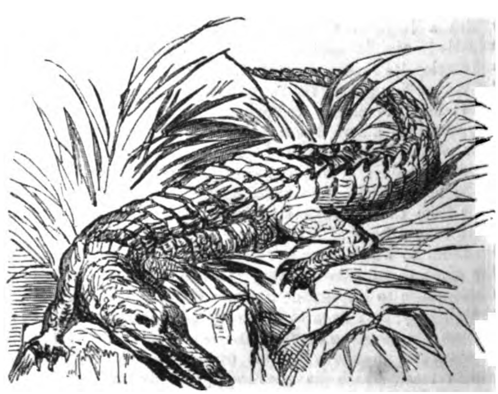
surface they present is very small. The animals are inoffensive, living chiefly upon roots and vegetables, and the insects which infest them. They dig burrows for themselves in which to sleep over the winter. Some individuals of the family have been known to live to an age extending over four or five human generations.

There is a genus differing from the above, and named the *Trionyx*, from having three of the toes on each foot furnished with claws. The carapace and plastron are not completely ossified, and are covered with a soft skin. The animal is highly serviceable in the Nile and other rivers in destroying young crocodiles and alligators.

ORDER SAURIA have generally four short legs; their mouth is always armed with teeth; their toes are furnished with nails, or the feet are palmated or webbed, according to their terrestrial or aquatic habits; the tail at the base is almost as thick as the body itself.

This order comprehends five families—Crocodiles, Lizards, Iguanas, Chameleons, and Scincoidiens.

Family *Crocodilidæ* (Crocodiles) are inhabitants of the rivers and fresh water of the countries bordering on the equator. They are huge and formidable animals, frequently attaining a length of twenty and thirty feet. The head is large, and each of the jaws, which are of an enormous length, is furnished with a single row of teeth. The back and tail are covered with strong plates or shields, so placed as to permit of free motion in all the parts of the body and limbs. The back is



Crocodile.

impenetrable to a musket-bullet. The legs being short and the feet palmated, the motion of the animal on land is necessarily slow; but in the water it moves with great rapidity, the tail acting as a large and powerful oar. This instrument, in which the scales assume the form of a serrated ridge, is a formidable weapon

of defence or attack. Like the vulture, the crocodile usually feeds upon the decayed carcasses that may come in its way; and it is thus of considerable service in those hot countries which it inhabits. But when it kills for itself, it frequently secretes the body of its prey in some hole at the edge of the water, where it is suffered to putrefy, after which it is swallowed without being masticated. The eggs, which are about the size of those of a goose, are deposited in the sand, and hatched by the heat of the sun. The females guard their young for the first three or four months of their existence, during which time they are in considerable danger of being devoured by the males, and other animals. There is only one genus of this family, *Crocodilus*, containing three species—1. The true *Crocodile*, which abounds in the Nile; 2. The *Alligator*, found in the large rivers and swamps of North and South America; and 3. The *Gavial*, which inhabits India and the islands of the Eastern Archipelago. The Malays consider the hunting of these animals excellent sport. Large parties, armed with pikes, pursue them in the marshes, and kill vast numbers of them.

Family *Lacertidæ* (Lizards) have the body elongated, and in general appearance resemble the Crocodile, though in point of size they bear no comparison to it. They are characterised by long slender tongues. Cuvier divides them into two genera—the Crocodile Lizards, and the True Lizards.

The Crocodile Lizards (*Hydrosauria*) derive their familiar name from their large size—some of them measuring upwards of six feet in length—and from having a crest of spines, similar to that of the crocodiles, upon the tail. In many species, also, the plate-coverings resemble those with which that animal is defended. They are sometimes called Monitors, because they warn each other of the approach of an enemy by a shrill whistling sound. They are mostly inhabitants of South America, frequenting the rank herbage of the savannas and the sides of rivers, where they feed almost exclusively on vegetable substances. Their flesh is considered a great delicacy.

The True Lizards (*Lacertæ*) are distinguished from the Hydrosaures by being covered with scales instead

Lizard.

of osseous plates or shields; as also by being strictly terrestrial in their habits, as their rounded tail indicates. This genus, by no means numerous, contains some of the most beautiful species of the saurians. Most of the European, and nearly all the British Lizards, belong to it. They vary in size from five to thirty inches. Their food consists of insects, frogs, and small mammals. They shelter themselves in old walls and dry places, and, except in tropical countries, pass the winter in a state of torpidity.

Family *Iguanidæ* (Iguana, or Guana Lizards) are so called from the name given to many of them by the natives of tropical America, where the most typical examples are found. They are chiefly distinguished from the true lizards by a short and thick tongue, with the extremity very slightly cleft. They live chiefly among the branches of trees, feeding upon leaves and fruit, together with insects and eggs.

This family has been divided into five genera—Iguana Proper, Gecko, Stellio, Polychrus, and Anolis.

Iguanas, properly so called, are, like the true lizards, covered with small imbricated scales; but are distinguished from these by a dorsal crest, and by the slender and compressed character of their tail. They also differ from them by having a large thin fold of skin, or dewlap, under the chin, and porous tubercles in the thighs. Each jaw is furnished with a range of triangular teeth, with the edges finely sharpened, and a double row also on the palate. They feed on vegetable substances, and live chiefly upon trees, though they frequently enter the water. Many of the species attain a length of four and five feet; and both their flesh and eggs are esteemed delicate food.

The *Geckoes*, or Nocturnal Lizards (*Platydactylus*), have not the attenuated form we generally find in reptiles of this order, but have a flattened body and a broad head, which, aided by their sombre colour, gives them a disagreeable appearance. Though the Geckoes are timid and harmless, they are always regarded by the vulgar as having a venomous character. They frequent buildings. Most of them present a curious organisation of the foot, by which the sole is converted into a sucker, enabling the animal to creep up vertical walls and along ceilings, like the flies upon which it feeds. They are common in the warm climates of the Old and New World.

Stellios have the depressed head and body of the Geckoes, and much of the same forbidding appearance; they are chiefly distinguished from them by their tails, which are encircled with rings of large scales. Their neck is narrow, and the head generally much enlarged behind by the muscles of the jaws.

The Marblets, *Polychrus* (πολύς, many, and χρόα, colour), are furnished with a large lung, which fills nearly the whole body, and subdivided into numerous cavities, gives them the power of changing their colour like the chameleon. Their ribs surround the abdomen, and form complete circles; and the tail, which is round, is more or less prehensile. They have no crest.

Anolis is the vernacular name in the Antilles of the lizard, to which the generic term Anolis is applied. They are remarkable for the faculty of inflating an appendage under the throat. They are light and agile in their movements; and in the beauty and brilliancy of their colour exceed all others of the saurian order. One species, the Basilisk, is distinguished by a mitre-shaped crest on the top of its head.

Family *Chameleonidæ* (Chameleons) are animals of

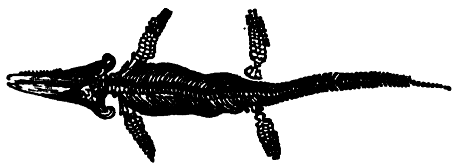
Chameleon.

small size, with a prehensile tail. They are readily distinguished from the other lizards by having scansorial or climbing feet, similar in their general structure to

those of parrots. They are natives of the warm parts of the Old World, and live in trees, which they seldom leave. Their prey, consisting of flies and other insects, is taken by darting out the tongue, which is terminated by an adhesive disk. They are capable of directing their eyes in two different ways at once—a faculty useful in giving information of the proximity of food in any direction. They are also remarkable for the power they possess of changing their colour, which is supposed to arise from the layers of the skin containing two kinds of pigment, situated at different depths.

Family *Scincoidæ* (Skinks, or Serpent-like Lizards) are so called from their general resemblance to snakes. Their feet are very short, their body much elongated, and they are for the most part covered with serpent-like scales.

Geology has made us aware that there was a period in the history of the globe, during which animals of this order, exhibiting some highly peculiar features, were the chiefs of creation, no mammalian animals then existing. The *Ichthyosaurus* was a marine animal, sometimes as



Ichthyosaurus.

much as twenty feet in length, possessing the vertebræ of a fish, with paddle-feet, like those of a turtle, and a crocodile-like head, armed with sharp and formidable teeth. Its fossil remains abound in the lias and oolitic formations. The *Plesiosaur* was a smaller animal, with a neck of extraordinary length, and a small head. It probably swam about on the surface of the water, arching its long neck in all directions on the outlook for fish, at which it would be able to dart its head, even to the depth of several feet. There were also land Saurians, of colossal size, the Megalosaurus, Geosaurus, and Iguanodon,

Pterodactyle.

the last being so named from its teeth resembling those of the Iguana Lizard, arguing herbivorous habits. But the most singular fossil saurian is the *Pterodactyle*. By

Flying Lizard.

an extraordinary development of the last digit, it was furnished with a pair of large wings, like those of the bat, and thus is supposed to have been enabled to pursue insects in the air. The only animal of the existing time approaching to the character of the Pterodactyle is the *Draco Volans*, or Flying Lizard, a small creature, possessing a membrane at its sides, by which it can float, as upon a parachute, from one tree to another.

Order Ophidia have the remarkable distinction of being destitute of limbs, yet are in their general characters so like saurians, that some naturalists decline to consider them as a separate order. In the possession of teeth, and in the scaly covering of their bodies, as well as in their general internal organisation, they closely correspond with the lizard tribes; and a further connection is shewn in the fact, that while some lizards have only two feet, some serpents shew the rudiments of the same number of limbs, though of no observable use. The serpents appear designed for a furtive life in grass and shrubbery, where they prey upon small animals. Their elongated bodies move in three ways—by alternate extensions and contractions, after the manner of worms, and by a series of arches, the straightening of which causes the head to keep continually advancing. 'They also coil themselves into a spiral by contracting the muscles on one side of the body, and by suddenly throwing into action those on the opposite side, the body being propelled as by the release of a powerful spring, with an impulse which raises it several feet from the ground, and projects it to a considerable distance.' They remain torpid during winter, and each season cast their skin. The tongue is forked. All are furnished with teeth, of which the greater number of species have three rows. A smaller number have only two rows; but as if to make up for that comparative weakness, these possess two fangs, containing poison—a peculiarity, it may be remarked, always inferring feebleness, or the want of other means of defence, in the animals exhibiting it. The serpent has from two to three hundred vertebræ; the head is small, but for its size has a large swallow, so as to admit of the prey being eaten entire. Like lizards and tortoises, the serpents are oviparous; but in some, the eggs are retained so long as to be in a manner hatched within the body of the parent, and thus are born alive.

The order comprehends five families.

Family *Anguinidæ* (Slow-worms) are generally of small size and harmless. In their structure they make an approach to the lizards, the bones of the pelvis and shoulder existing in a rudimentary state under the skin. The common Slow-worm, or Blind-worm, of this country has received its second name from the supposed absence of eyes; this is an absurd error, however, as the eyes, though small, are very brilliant. It is a perfectly harmless animal, feeding on insects, slugs, &c. It is said to swallow frogs, birds, and mice; but this is impossible, as the bones of its jaw do not separate in the middle, and its swallow is consequently small and not dilatable. When alarmed, it throws the whole of its muscles into contraction in a peculiar manner, and is then very brittle, so that it frequently loses its tail by various accidents; in the course of a year, however, this member is replaced. There is a larger species of this family existing in America, which attains the length of two feet, and from its extreme brittleness is called the Glass-serpent.

The *Hydrophidæ* (Water-serpents) are comparatively few, and are limited in their geographical range. They are mostly found in the seas and rivers of the East Indies, and in some localities they are by no means uncommon. They are chiefly known by the very decided vertical compression of the tail and hinder part of the body, which may thus be compared to the tails of fishes; hence they swim with considerable facility, occasionally coming to the surface to respire. They possess poison-fangs, and are more dangerous than crocodiles or sharks to persons entering the water where they abound.

The *Amphisbænidæ* (Double-walkers) are a still

smaller group, intermediate in some respects between the slow-worms and the true serpents. They derive their name from the power of moving backwards or forwards with equal facility. The two extremities of the body are so much alike, that they would not be distinguished by a superficial observer, the eyes being so very small as sometimes to appear wanting; the whole body is of nearly equal diameter. This group is restricted to the warmest parts of South America. Notwithstanding the common idea of its venomous properties, it is quite harmless, and subsists on ants and other small insects. It has not the power of separating the bones of the jaws, which distinguishes the true serpents.

Family *Crotalidæ* includes the great bulk of the venomous species. Their type is the Rattlesnake, so called from the sound produced by a series of horny rings at the extremity of the tail when the animal is in motion. The poison-fangs are each pierced by a small canal, which gives issue to a poisonous fluid. When not in use, these lie incased in the upper gum; but when the animal is irritated, they are unfolded, and struck into the victim, the poison being at the same time ejected with great force by the action of the muscles that shut the lower jaw. The matter is poisonous only when introduced into the blood. The bite of the rattlesnake produces almost instantaneous death; but they never attack man unless when trodden on or provoked. Their food consists of birds and small animals; and such is the terror with which they inspire these creatures, that it often renders them incapable of saving themselves by flight. This may have given rise to the supposition that rattlesnakes had the power of fascination. Some species are from five to six feet in length, and about the thickness of a man's arm. Besides their other peculiarities, this genus is also remarkable for a deep hole behind each nostril, the use of which has not been ascertained.

The Vipers (*Vipera*, a contraction of *vivipar—virus*, alive, and *paro*, I bring forth) are produced from eggs; but in the act of deposition, the covering is broken, and the young come forth alive. They are distinguished from the former genus by a broader head, and by the absence of the rattle, as well as the cavities behind their nostrils. Vipers are most abundant in hot countries, where they attain the largest size. The Common Adder and the Black Adder are the only two species of venomous serpents indigenous to Britain.

Puff Adder.

Family *Coluberidæ* (True Snakes).—This group, which is non-venomous, and very extensive, includes all those serpents in which the subcaudal plates are arranged in pairs, thus comprising the largest serpents in existence. Most of the family have the greater number of the characteristic properties of the order highly developed. This family, *Coluberidæ*, consists of Boas, Pythons, and Colubers.

The *Boa Constrictors*, which are peculiar to the tropical regions of America, are characterised by having the under part of the body and tail covered with transverse shields. Many of the species have been known to exceed forty feet in length, and they can swallow large animals, such as sheep and even oxen. This they effect by coiling themselves round the body of the victim, and crushing it till every bone is broken. They then moisten it with saliva, and proceed to swallow it. The *Pythons* are inhabitants of Asia, and differ from the Boas principally in having the plates under the tail double. Though many of them are as large as the Boas, yet they feed on birds, rats, and other small animals. The serpents exhibited in this country under the name of Boa Constrictors are mostly Pythons. The *Colubers*, properly so called, are inhabitants of Europe. They sometimes attain a length of six or seven feet. In appearance they resemble the Pythons, and, like them, feed on small animals—such as insects, mice, and frogs. They prefer marshy situations.

There is also an important group of coluberiform serpents which are venomous, inhabiting India and Africa. They are externally distinguished by little more than the comparative thickness of the muzzle.

Cobra da Capello.

The most formidable of the group is the *Cobra da Capello* of India, the bite of which is fatal within an hour.

ORDER BATRACHIA (from Βάτραχος, a frog) includes frogs, toads, and such reptiles as have no scales, but a naked and moist skin. They are remarkable for a curious peculiarity attending their reproduction. On issuing from the egg, they are in an immature state, possessed of gills, and thus fitted to live in the water. The order comprehends three families, respectively represented by the Frog, Toad, and Newt.

Family *Ranidæ*, or Frogs (*rana*, a frog), are so well known that a description of them seems unnecessary. Their power of leaping is remarkable, and they are the best swimmers of all four-footed animals. They are of a yellowish brown colour, with black spots. Their mode of breathing is one of the most curious characteristics in their organisation. Their inspiration is effected by the muscles of the throat, which, by dilating, draw in air through the nostrils. The contraction of these muscles, while the nostrils are closed by the pressing of the tongue against their interior orifices, and the mouth at the same time being shut, compels the air to enter the lungs. The animal would thus be choked if the mouth were kept open. Their expiration, on the other hand, is produced by the contraction of the muscles of the abdomen. In cold regions, frogs pass the winter in the ground, or in mud under water, without eating or

breathing. The spawn, consisting of a vast number of eggs, each of which is surrounded by a covering of transparent glutinous matter, is deposited at the bottom of some stagnant pool early in spring. Owing to some partial decomposition, and the consequent disengagement of a gas, the entire mass becomes lighter than the surrounding water, and rises to the surface. The young then burst from their prison, and feed on vegetable matter. In the early stage of their existence, they are called tadpoles, and are of a black colour. They breathe by gills, and are characterised by a round head and long tail. In this state, they may be regarded as fish in all essential respects. They increase for a time rapidly in size, without undergoing much change in form, till they attain a length of about an inch. The hind feet are then developed; next, the anterior extremities assume their ultimate form, the tail is gradually absorbed, the hinder part of the body becomes rounded, and the beak falls off, discovering the true jaws. The eyes, which in the tadpole were only discerned through a transparent spot in the skin, become visible with their three lids; the gills are obliterated. As soon as they have effected their metamorphoses, they breathe by lungs, and become carnivorous, feeding upon insects, slugs, and similar animals. The Common Frog (*R. Temporaria*) is the only species indigenous to Britain.

The *Surinam Frog* is remarkable for being much smaller in the mature than in the immature state, the tadpole being fully eight inches long, while the frog is diminished, chiefly by the loss of its tail, to three.

The Tree-frogs (*Hylæ*) differ from the common frogs chiefly in having their feet provided with suckers—a conformation which enables them to adhere to the surfaces of bodies, and even climb trees. This they do in pursuit of insects. These also lay their eggs in the water, and hibernate during winter. They are natives of America, and many parts of Europe; but are never found in Britain.

Family *Bufoidæ* (Toads) resemble the frogs in figure, but are of a dull cadaverous hue, and covered with warts. Their movements are slow. They are characterised by a swelling above each eye, from which a fetid milky excretion is expressed; but this is said to be destitute of any venomous quality. They are useful in gardens, as they feed on worms, slugs, and wasps; yet they are hated and persecuted by the ignorant. They seldom frequent the water, but for the purpose of depositing their eggs. Their hibernation is passed on land, either in some sheltered space, or in burrows which they excavate for themselves beneath the surface of the ground. Two species are found in Britain, the *Common Toad* and the *Natterjack*. The former progresses more by leaping than crawling; and the latter does not leap, but creeps, which it does with considerable celerity. The natterjack is found in the heaths of the south of England. Other species are the *Bombinator*, the *Rhinella*, the *Antilophus*, the *Breviceps*, and the *Pipa*.

The family of Salamanders, the largest of which does not exceed two feet in length, have the body and tail elongated. They bear a strong resemblance to the lizards in their general form, but are easily distinguished from them by their smooth soft skin. They may be subdivided into three genera—the True Salamanders, the Tritons, and the Amphibious Newts.

The *True Salamanders* remain in the water during their tadpole state. In their adult condition, they live principally on the land, and frequent their original element only for the purpose of depositing their young, which are produced alive. There are few of these reptiles in Europe; in America, many have of late years been discovered. The surface of their bodies, like that of the toad, is somewhat warty, and they have a gland containing an acrid secretion said to be poisonous. Their tail is cylindrical, or rounded. Eggs are hatched within the body, and young are produced alive. These animals prefer damp and humid places, particularly at the edges of walls, hiding among rank grass, where their food, which consists of slugs and worms, is readily procured.

Newt.

The *Tritons*, or *Aquatic Salamanders*, commonly called *Newts*, pass the greater part of their life in the water. Their tail, which is their chief organ of locomotion, is vertically compressed, or oar-shaped. They possess the extraordinary power of reproducing limbs that have been cut off. There are three species indigenous to Britain.

The *Amphibious Newts* (*Amphineusta*) which are similar in form to the two preceding genera, breathe both by lungs and gills, respiring by the former on land, and by the latter in water; and are the only true amphibians among vertebrated animals. This genus, consisting of the Proteus, the Syrens, and some others, are chiefly inhabitants of the American continent.

CLASS BIRDS.

The third class of vertebrated animals is the BIRDS, in which we for the first time find a complete double system of circulation, attended with its proper consequence of warm blood, while yet they maintain the oviparous mode of reproduction which we have seen in Reptiles, only with the additional peculiarity of a hatching and nurturing of the young by the parent. The most remarkable external features of the class are—the having the body covered with feathers instead of hair or wool, and, as a rule, the fore-pair of limbs adapted to serve as wings, in enabling the animal to maintain flight in the air. In their internal structure, birds are distinguished by having the lungs, which are larger than in the mammalia, fixed to the ribs, and pierced in such a way as to permit the air not only to pass into the chest, but also into various other cells, that can be inflated or emptied at pleasure. This organisation, by increasing their buoyancy, adapts them to range over the aërial regions with an ease and celerity to which there is no parallel in nature. Their powers of vision are more highly developed than those of any other class of vertebrated animals, the eye being generally so constructed that they can see objects far and near with almost equal clearness.

The posterior extremities of birds serve as the sole support of the body on the ground, and are usually placed rather far back. Most commonly, the feet exhibit four toes, of which one is directed behind and three in front; besides which there is, in the fowl tribe, a *spur* behind, analogous to the thumb on the human hand. In the ordinary single posterior toe, the number of joints is only two; in the external, it is five. The toes terminate in claws, and these are of great strength and sharpness, where they are to be used in clutching and tearing prey.

Birds have no teeth, properly so called, and cannot therefore masticate their food, which is either torn by the beak or swallowed whole—its reduction to a soft and pulpy state being entirely performed in the stomach. The plan of the digestive system most usual in this class is that which is exemplified in the common fowl. The stomach consists of three cavities: the first being formed by an expansion of the gullet, which produces a bag or chamber known as the *crop*. In this receptacle the food is stored up, and transferred by degrees to the second or membranous stomach, where it is softened by the action of the gastric-juice. It is then conducted to the *gizzard*, or third cavity, in which the process of digestion is completed. This last stomach presents modifications varying with the nature of the food upon which the bird subsists. If it feeds on grain, the sides of this stomach are of considerable thickness, and are moved by powerful muscles, which act as a mill in grinding down the food; but in those species which subsist on animal substances, or soft herbage, the muscles are reduced to extreme delicacy. In many cases the process of digestion is promoted by the swallowing of small pebbles, which, being brought into contact with the food in the gizzard by the muscular action of the stomach, produce an effect similar to that of teeth, and in some measure serve the purpose of these agents.

The change of the plumage, termed *moulting*, generally takes place annually; while with some species a partial casting of the feathers occurs also at the breeding-season. Many birds migrate from one latitude to another, chiefly for the sake of obtaining a better supply of food. The summer immigrants that visit our island—as the swallow, the rail, and the cuckoo—are from tropical regions; while all winter visitants—as the swan and the wild-goose—come from the north. The northerly position is the one adopted by the latter for their summer residence, and the bringing forth of their young.

Not only do birds resemble insects in their general structure and mode of life, but also in the peculiar development of the instinctive powers. Under the direction of these, the place for their nests appears to be selected, their materials collected, the nests themselves built, and the young reared in them, the migrations are performed, and many curious stratagems are employed to obtain food. It is sufficient thus to indicate these features in general terms, since it is well known that each species has some peculiar habits, while in all the individuals of each, they are as precisely alike as their circumstances will admit. Nevertheless, there is observed in birds a degree and adaptation to varying conditions which insects do not possess, and an amount of *intelligence* superior to what is found in that class. And in the domesticability of many tribes of birds, we see an obvious approach towards that higher form of attachment to man which is exhibited by many species among mammalia.

Birds are of great utility to man, not only as an article of food, but also by keeping in check noxious animals; as insects and snakes, and in consuming carrion and other refuse.

Natatores.

ORDER NATATORES, or *Swimmers*.—A considerable number of the birds are adapted to an aquatic life, and spend great part of their time upon the surface of the sea, or on rivers and lakes. These are regarded as forming a distinct order, characterised by that webbed form of foot which serves for swimming, and named accordingly *Swimmers*, though in reality the order includes birds of great variety of character, both in form and in disposition and habits. The legs are short, and placed behind the point of equilibrium. The body is closely covered with feathers, and coated with a thick down next the skin. It is in this order that we find the nearest approach to reptiles which is to be found amongst the birds.

The *Alcidæ* (Auk tribe) exhibit the most remarkable adaptation of the structure of the bird to an aquatic life, with which the entire order presents us. This is best seen in the *Penguins*, whose wings are very small, and covered with mere vestiges of feathers, resembling scales; so that they serve as admirable fins or paddles, but are totally useless for flight. The feet are placed very far back, so that when upon land the bird stands nearly erect. Having no power of flight, and not being able to run, the penguin may be overtaken with ease upon land; but once in the water, it distances its pursuers, swimming with the ease and rapidity of a fish, and springing several feet over any obstacle that may impede its course. Besides other characters which are considered as indicating an approach towards the reptiles in this tribe, the penguin is especially remarkable for having the kind of ball-and-socket union of its vertebræ which is peculiar to that class. They are exclusively inhabitants of the southern seas; but there are birds of the northern ocean which approach them in their peculiar characters. Such are the *Puffins* and *Auks*, the former of which have short wings, capable of sustaining them for a little while; of the latter, one species has wings well adapted for flight, whilst in the others the wings are adapted to aquatic progression almost as exclusively as in the penguin. The Puffin, which comes to Britain both from the north and south, and is often found breeding in old rabbit-holes near the sea, has a short deep narrow bill, and horny appendages over its eyelids. Watching on

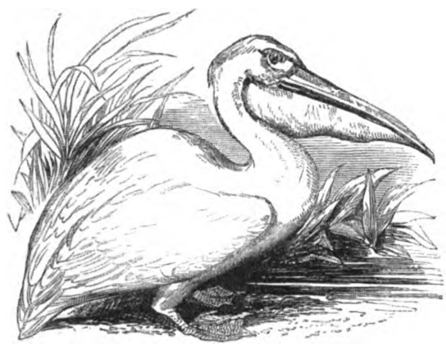
Puffin.

cliffs over the sea, it no sooner sees a proper prey, than it plunges like a dart into the water, and often captures three or four sprats at once.

In the family *Colymbidæ* (Divers), as in the penguins, the wings are remarkably short, and the feet placed so far behind the point of equilibrium of the body, that they are ill adapted for walking. Of the genus *Colymbus*, the *Northern Diver* is a familiar example. It is generally an inhabitant of the most northern parts of the Old and New World; but on the approach of winter, it journeys southward, and is then occasionally found in Scotland. It is said to be able to swim below the surface of the water for a couple of hundred yards, in pursuit of its prey, which consists of small fish. The *Guillemots* bear more resemblance perhaps to the auk family, but resemble the divers in using their wings to propel themselves under water. The *Grebes* (*Podiceps*) are more inland in their habits, living chiefly on the borders of lakes. The toes are separate, but each has a fin-like membrane along the side, presenting a considerable surface to the water.

Family *Pelicanidæ* (Pelicans) consists of three genera, represented by the Pelican, Cormorant, and Solan Goose.

The *European Pelican*, which may be taken as a representative of the Pelican genus, is as large as a swan,



Pelican.

and altogether white. It has a long, slightly curved bill, and is remarkable for possessing a large neck-pouch, in which it stores provisions and water. The bird makes its nest in marshes, but roosts on trees.

Genus *Phalacrocorax* (Cormorants).—The *Black Cormorant* is about the size of a goose, and of a bronze black colour. It is very common on the British coasts, and in former times it was trained in Europe, and still is by the Chinese, for fishing, as hawks are for fowling. The cormorant is proverbial for its voracity. It carries on its ravages by night and by day, diving to catch its prey, which it can pursue for nearly one hundred yards below the water, before it is obliged to come up for air.

Genus *Sula* (the Gannet or Solan Goose).—These birds take their prey by hovering in the air at some little distance above the surface, and then dropping down upon any fish that they may see rising within their reach. The air-cells are very largely developed, especially under the skin of the breast, which is almost completely separated by them from the muscles beneath; and it is probable that they may serve as an elastic cushion, to break the force with which the body of the bird would otherwise impinge on the water. These birds haunt the cliffs of solitary islands, for the purpose of bringing forth their young. The Bass Rock in the Firth of Forth, and Ailsa in the Firth of Clyde, are noted habitations of the *Solan*. It is eatable, but forms rather a coarse dish for most palates.

Family *Anatidæ* (Ducks) is divided into three genera, represented by the Swan, the Goose, and the Duck.—They are all remarkable for a broad bill, horny at the extremity, while the rest is invested in a membrane, and terminates at the edges in laminæ or little teeth, forming a kind of strainer for gathering food in a watery element. The birds of this family are highly serviceable as food.

Genus *Cygnus* (Lat., a Swan).—There are several wild species of this genus, of which the most remarkable is the *Hooper* or *Whistling Swan*, a native of the arctic regions, but which migrates southward in flocks, headed by a leader, and ranged in the form of the letter V, when their loud notes are occasionally to be heard, softened by distance. The tame Swan (*C. olor*), called the *Mute Swan*, to distinguish it from the preceding, is a beautiful ornament to our rivers and lakes. It is one of the most elegant birds, lives almost entirely upon the waters, and feeds upon aquatic plants, frogs, and insects. Swans are remarkable for their longevity, some having been known to live a hundred years.

Genus *Anser* (Lat., a Goose) presents several wild and migratory species both in the Old and New Worlds. They all live upon vegetable substances, and are consequently useful as food. The *Canada Goose* going northward every summer, is of great service to the Hudson's Bay residents, who kill and preserve great quantities for their winter provision. Our own tame species is supposed to be derived from the *Gray Lag Goose*, once very abundant in the fenny districts of Lincoln and the neighbouring counties, and permanently resident, but, like other species, now only seen in small flocks as a winter visitant.

Eider Duck.

Genus *Anas* (Lat., a Duck) includes many species, as the Velvet Duck, the Eider Duck, Shoveller, and Sheldrake; all of them wild animals, frequenting pools and other waters remote from human haunts. The *Mallard* is the parent race of all the common ducks. It is permanent in many parts of Scotland in lakes and marshes, but receives a vast accession to its numbers on the approach of winter from northern countries. The habits of the *Common Duck* are familiar: in its researches for food amongst mud and turbid waters, it is understood to be much assisted by the sensitive skin of its bill, which enables it to feel, or, as it were, grope for objects which it may devour.

Family *Laridæ* (Gulls).—This tribe performs the same office on the sea that vultures do on land, feeding upon carcasses of every description that float on its surface, or are cast upon its shores. They are found in all latitudes, but are larger and more numerous in the northern regions. They are arranged into five genera—Gulls, Terns, Skuas, Petrels, and Albatrosses.

Genus *Larus* (Gulls Proper).—The *Common Gull* (*L. vulgaris*), the type of the genus, is about one foot and a half in length, and three feet in the expanse of its wings; above, it is of a bluish-gray, and white beneath. It makes its nest of sea-weed, on the ledges of rocks on the coast. On the approach of stormy weather, it has a propensity to leave the shore, and to sail round and round in circles at a great elevation.

Genus *Sterna* (Terns) are sometimes called *Sea-swallows*, from the resemblance they bear to the land-swallow in their long pointed wings and forked tail. They are also similar to that bird in their port and flight, but differ very much from it in their habits. Their food consists of mollusks and small fish. The tern is often seen chasing a small gull, and, as it were, persecuting it, in order to force it to disgorge the fish it may have taken. As soon as the fish has been dropped, the tern descends like an arrow, and generally succeeds in catching the meal before it reaches the surface of the water. The *Common Tern*, which is about fourteen inches in length, is a periodical visitant in Britain, arriving in April and leaving in September. In very stormy weather, it may be seen following the river-courses in pursuit of its prey.

Genus *Lestris* (Skuas) are nearly allied to the Terns, but are more powerful birds. Their peculiar habitation in this country is the Shetland Islands, where they nestle and breed in communities on wild and unfrequented heaths; but as soon as the breeding has ended, they go each its own way to the adjacent seas, and lead a solitary life, feeding on fish-offal and animal matter. Like the terns, they pursue gulls till they oblige them to disgorge what they have swallowed. The entire length of the *Common Skua* is about two feet; the wing measures sixteen inches, and its general colour is a reddish-brown.

Genus *Procellaria* (Petrels).—The name *Petrel* is a diminutive of Peter, and has been applied to those birds from their habit of walking on the waves. This they effect by striking their feet rapidly against the water, and at the same time supporting themselves with their wings. One species, the *Giant Petrel*, is as large as a goose; it is found only in the South Seas. The most common one, called by mariners *Mother Carey's Chicken*, is found in most seas. When it seeks shelter upon vessels, it is generally supposed as indicative of storms and shipwrecks. During the greater part of the day, it conceals itself in holes and crevices of rocky shores; in the evening, it comes forth, and flies close over the surface of the sea, in search of floating insects and dead animal matter. This species is of a brownish-black, and it differs little from the common swallow either in size or appearance.

Genus *Diomedea* (Albatrosses).—The *Common Albatross* (*D. exulans*) is the most bulky of all aquatic birds, measuring twelve feet and upwards between the extremities of the wings, and has a wide range upon the ocean, but abounds chiefly within the tropics. It has a large, strong, trenchant bill, marked with sutures or joinings, and terminating in a stout hook. It is very voracious, and is said to destroy numbers of flying-fish, when they are forced to seek refuge in the air.

Grallatores.

The Order of Grallatores (*Waders* or *Stilt-birds*) derive the name from their habits and conformation. Their long legs raise up their bodies, as it were upon stilts, and thus elevated, they frequent the banks of rivers, lakes, marshes, and the shores of estuaries; and whilst resting with their feet upon the land, derive their nourishment chiefly from the water—some feeding exclusively upon small fishes, aquatic mollusca, worms, small reptiles, and water-insects—whilst others are more terrestrial in their habits and mode of feeding. Such as are more especially aquatic have a short web to their toes. Their wings are long, affording them that power of changing their habitation with the seasons, which most of them enjoy. During flight, they stretch out their long legs behind, to counterbalance their long necks; and the tail is always extremely short, its function as a rudder being transferred to the legs. They mostly construct their nests upon the ground; and the young are enabled to run about as soon as hatched, except in those species which live in pairs.

Family *Gruidæ* (Cranes).—Of this family we shall notice only one species, the *European Crane* (*Grus*

Crane.

cinerea). In Britain its appearance is now exceedingly rare, though in former times it was well known in many parts of England. It is described as a beautiful sight to witness thousands of them passing over the Mediterranean, northwards and southwards, as the case may be, in marshalled order, in groups of from twenty to sixty, and each group headed by one of the larger birds. It is with reference to the regularity of the migrations of these birds, that Jeremiah, viii. 7, says: 'Yea, the stork in the heaven knoweth her appointed times.' The crane roosts on the ground in open situations void of trees, and its food consists almost exclusively of vegetables. Its length is nearly five feet, and its weight about ten pounds.

Family *Ardeidæ* (Herons).—The *Common Heron* (*Ardea cinerea*) is of very general distribution, and is a well-known bird in Britain. It passes the winter in the southern parts of Europe and in the north of Africa, migrating thither in autumn, and returning northward in spring. The extreme length of the Heron is about three and a half feet; its general colour is an ashy gray with a bluish tinge; and its head is ornamented with a crest. It builds on lofty trees, especially on oaks, in the neighbourhood of streams and marshes. The heron is very expert in catching fish, on which it principally feeds, though it does not despise mice and reptiles.

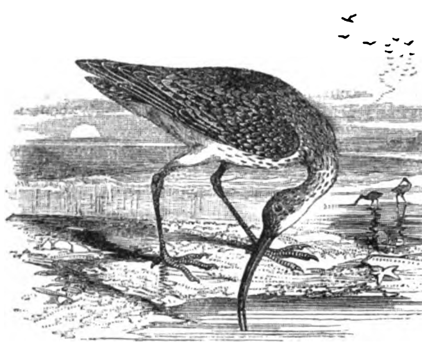
The *Bittern* or *Mire Drum* (*Botaurus stellaris*), a species of heron, was once well known in Britain, but is becoming rare as waste lands are reclaimed. Its general resorts are extensive swamps covered with tall flags and rushes. The bittern is the emblem of desolation, and as such is spoken of by the prophet in his denunciation against Babylon: 'I will also make it a possession for the bittern, and pools of water: and I will sweep it with the besom of destruction, saith the Lord of hosts.' The booming of the bittern is peculiarly dismal. It resembles the interrupted bellowing of a bull, but is more hollow, and is heard at the distance of a mile. From this circumstance, and the lonely marshes it inhabited, it was the unconscious hero of many a ghost-story in the superstitious ages that are past.

The *Stork* (*Ciconia alba*) stands about four feet high. It migrates in summer from Africa into a wide range of more temperate latitudes, and, in many countries widely apart from each other, is held, as it were, sacred, on account of its destruction of vermin. This has rendered it very familiar, and in Holland they prepare false chimneys on the tops of their houses, that the stork may build in them, each regularly returning to its own nest every year. Owing probably to the improved drainage of the country, the stork is now a rare visitor of Britain.

The family *Scolopacidæ*, composed of Snipes and Woodcocks, has the Wood-cock (*σκολόπαξ*) for its type. These birds are remarkable for their long and slender bills, the use of which is restricted to searching in the mud for worms and insects. To this family belongs the *Ibis*, an African species, once held in great veneration in Egypt, and embalmed by the ancient people of that country, in consequence, it is supposed, of its usefulness in devouring serpents.

The *Wood-cock* is a well-known species in Britain, where it arrives in flocks from the northern countries. It is about the size of a pigeon, and has finely mottled plumage. It feeds on worms and insects, which it searches for with its long bill in moist situations, under the cover of young trees, and near hedges by the sides of rivulets. As an article of food, it is much esteemed for its exquisite flavour. The *Common* or *Whole Snipe* is one of the most common winter visitants of the British Isles. It chooses swampy parts of meadows; and small worms, insects, and vegetable substances seem to constitute its food. Its entire length is about twelve inches, and weight about four ounces. The *Half* or *Jack Snipe* is a minute species, its length being only eight inches. It resembles the other in its habits, only it is more solitary. The *Curlew* also belongs to this family. It is a well-known bird, haunting sandy shores during the whole winter for

minute crustacea and worms, and breeding in summer on heaths and bogs. The name is derived from the bird's peculiar cry.



Curlew.

Family *Rallidæ* (Rails) consists of five genera—Gallinula, Fulica, Rallus, Jacana, and Phœnicopterus.—The *Water-hen* is a species very common throughout Europe. In summer, it is found in almost every pond, lake, and quiet water-course. Its colour is a deep olive-brown above, and slaty-gray below, with a frontal shield of bright red. It is rather more than a foot in length, and weighs about fifteen ounces.

The *Coot* (*Fulica atra*), a well-known bird, found wherever there is a pond, is migratory, and arrives here in large flocks from more northern latitudes, though many of them are constantly resident. Its size is equal to that of a common fowl.

The *Rails* (*Rallus*).—The *Landrail* or *Corncrake* (*R. pratensis*) is a regular summer visitant in the British Isles. It conceals itself so well among the grass and young corn, that were it not for its cry, few persons would be aware of its presence amongst us. It is larger than a black-bird, and is of a reddish-brown colour.

Landrail.

The *Jacanas* and *Flamingoes* are classed with the Rail family. They inhabit the marshes of hot countries. The common species of the flamingo, *Phœnicopterus* (wings of flame), is from three to four feet in height. It is purple-red on the back, and has rose-coloured wings. The mandibles are abruptly bent downwards, about the middle of their length; and they are roughened at the edges, like those of the ducks, to which the fleshiness of the tongue also shews an alliance. They feed on mollusca, insects, the spawn of fishes, &c., which they seize by means of their long neck, turning the head downwards, to use to advantage the crook in the upper mandible. They construct their nests in marshy situations, placing themselves astride of them during the act of incubation, being incapacitated by the length of their legs from sitting on them in the usual manner.

Flamingo.

The *Charadriadæ*, or *Plover tribe*, are less aquatic than most of the other families. The legs are long, and the back-toe is either quite absent, or so short as not to reach the ground. They live only on sandy and unsheltered shores, or on exposed commons, congregating in flocks, and running with great swiftness. The bill is usually of moderate strength, enabling these birds to penetrate the ground in search of worms, to obtain which they have the habit of patting with their feet, which causes the worms to rise. The species in which the bill is more feeble, frequent meadows and newly ploughed land, where this food can be obtained with greater ease; those which have stronger bills subsist additionally on grain, herbage, &c. Of the plovers, several species exist in Britain, and others are distributed through most other countries. Some chiefly frequent the sea-coast, and others the upland moors. The *Lapwings* are nearly allied to the plovers, and, like them, are migratory, passing the winter in warm latitudes; they are peculiar to the Eastern Hemisphere. They are very noisy birds, screaming at every sound they hear, and defending themselves with courage against birds of prey. They derive their name from the stratagem by which they lure away intruders from their nests: they drop their wings in flight, appearing as if wounded, and thus induce their pursuers to follow them to a considerable distance.

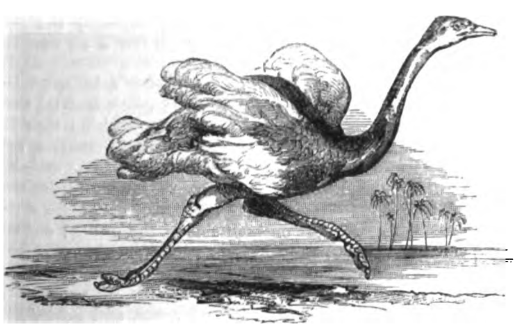
Three other genera of this family are worthy of notice. The *Bustards* connect the Grallatores with the Rasores in the heaviness of their bodies, the small membrane at the base of their toes, and some other characters. They have, however, the long naked legs of this order, and the flavour of their flesh resembles that of the wading-birds. They fly little, scarcely ever using their wings, except, like the ostriches, to assist them in running; but their flight, when they do rise, is easy, and capable of considerable duration. They feed equally on grain, herbage, worms, and insects. The great bustard is the largest of European birds, and is one of the finest kinds of game; it has been nearly extirpated in Great Britain. The *Turnstone* is at once recognised by a short stout bill, rather turned upwards; the name is derived from the habit it possesses of turning up stones on the sea-shore, to feed upon the marine animals concealed beneath. The *Oyster-catcher* has a long, straight, wedge-shaped beak, which is strong enough to enable it to force open the bivalve shells of the mollusks upon which it feeds.

Cursores.

Order Cursores, or *Runners*, exhibit a remarkable exception from the class in general, being without powers of flight, and possessing at the utmost only the

rudiments of wings. Instead of such powers, these birds have remarkably strong limbs, adapted for rapid running over the wide-spread plains which they inhabit. Hence their name as an order. In some respects they approach the mammalian character, their feathers being much like hair, and one of the family having the rudiment of both a diaphragm and a bladder, wanting in birds in general.

The *Ostrich* is a well-known bird in the tropical parts of the Eastern Hemisphere. Its specific name of *Struthio camelus* was conferred in allusion to certain points of analogy between it and the camel; it is an inhabitant of the wide-spread deserts of Africa and Arabia. It is incapable of flight, but is remarkable for its swiftness of foot, being able to outstrip the fleetest horse. The height of the adult male is from seven to eight feet in the upright position. The *Great Bustard* (*Otis tarda*), which may be considered as the European representative of the ostrich, was once common in Britain, where, however, it is now of rare occurrence, being chiefly confined to the county of Norfolk. It runs with extreme rapidity, and, unless closely pursued, seldom takes wing. It frequents extensive plains, and nestles among the corn. Its weight is from



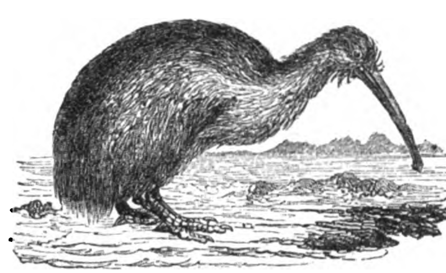
Ostrich.

twenty-five to thirty pounds, and its flesh is much esteemed. The *Little Bustard* (*O. tetrax*) is scarcely half the size of the preceding species, and less widely diffused.

Of the *Rhea*, which is peculiar to South America, there are only two well-defined species. By travellers they are called ostriches. One of the species in its natural attitude stands about five feet high; the other is of smaller size. The plumes of these birds are imported into this country, and are often seen fixed in a handle, so as to form dusting-brushes.

Of the genus *Dromaius*, the *Emu*, or *New Holland Cassowary*, is the type. It nearly equals the ostrich in bulk, but is lower on the legs, and more thickset in body. Though not an aquatic bird, the emu swims well. There is only one example of the genus *Casuarius*, and it is a native of Java, Sumatra, and the Moluccas. Its pinions are very small, and concealed beneath the plumage. The beak, instead of being broad and depressed, as in the ostrich, is compressed laterally, and ridged above. The head, which is naked, is surmounted with a horny crest or helmet. The height of this bird when erect is about five feet, and it is very strong. Its food consists of fruits and tender juicy herbage.

The *Apteryx* is limited to New Zealand. It stands about two feet in height. It has merely the rudiments of wings, buried beneath the general plumage of the body; but, like the ostrich, it runs with great swiftness. When chased, it takes refuge in the clefts of rocks, in hollow trees, or in deep holes, which it excavates in the ground. Its food consists of insects and worms. Night is the season of its activity, and the natives hunt it by torchlight. The skin, prepared with the



Apteryx.

feathers on it, is highly prized by the chiefs as an article of dress.

Rasores.

The Order Rasores (*Scrapers*)—nearly corresponding with the Gallinaceæ, or Poultry tribes—consists of land-birds of bulky bodies, generally vegetable, or rather grain-feeders, gregarious in their habits, and readily domesticable. The name of the order is derived from a noted habit which serves them in seeking for food. They furnish man with a considerable amount of savoury and wholesome food, and their fecundity is very great. The majority of them are at once known by their strong thick legs, long necks, short wings, and large ample tails; and the heads of many, especially of the males, are ornamented with elegant crests. The form of the bill is well seen in the common cock; the upper mandible is vaulted, and at the same time destitute of any notch; the whole is short and strong, having a peculiarly horny appearance. The wings are muscular, but their feathers have rounded ends; and the breast-bone presents a comparatively small surface for the attachment of the muscles, so that the power of flight is not great. Almost all of them have a large crop, and an extremely muscular gizzard.

The Rasores, in general, deposit and hatch their eggs on the ground, in a rudely constructed nest of straw; but some of them, which reside in forests, build in trees. Each male usually associates with many females; he takes no part in the construction of the nest or in rearing the young, and these are generally numerous, and able to run about and provide for themselves the moment they quit the shell. When this is the case, the male is larger and more gaily coloured than the female. But in the few species which associate in pairs, such as the ptarmigan and partridge, the sexes nearly or quite resemble each other, both in size and colour.

The Rasores are usually divided into four families—Pheasants, Curassows, Partridges, and Pigeons.

The *Phasianidæ* (Pheasant or Fowl family) are distinguished by the shortness of the hind-toe, the presence of spurs on the legs, and the beautiful development of the tail. Overlooking the turkey, they are birds of the Old World. They may be considered as forming the type of the order. It is in the hotter parts of India that the most brilliantly coloured birds of this family present themselves in greatest numbers.

The *Pheasant*, which again may be regarded as the type of the family, derives its name from the Phasis, a river of Colchis, in Asia Minor, from which district it was first introduced into Europe. Several very handsome species abound in different parts of Asia. Among these, one of the most remarkable is the *Argus pheasant*, inhabiting Sumatra and the south-east of Asia. The wings are large, and are covered with eye-like spots, which give a very remarkable appearance to the bird. There is a large poultry-bird in New Holland, which has

been sometimes placed among the vultures, but which certainly belongs to this order. This is the *Vultern:* its chief point of resemblance to the vultures is its bald neck; it has also some affinity with the next group, especially in the absence of spurs and the size of the hind-toe.

The *Peacock* is a native of the forests of India. Its beautiful tail, or rather train (for the proper tail exists

Peacock.

underneath), has made this bird a favourite in the ornamental grounds connected with English country mansions. Alexander the Great found the peacock flying in great numbers in India, and introduced it into Europe, where at first it was shewn for money as a curiosity. The plumage of the *Impeyan*, also a native of the north of India, resembles that of the humming-birds upon a large scale; it can only be compared to the most refulgent hues of variously coloured and finely polished metals.

Our well-known domestic poultry, the *Common Cock* and *Hen*, are supposed to have originated in the Indian Archipelago, and to have been introduced at a still earlier period into Europe. Their usefulness and general habits are too familiar to require description. The *Turkeys* are the only representatives of this group in the New World, whence they were brought by the early discoverers, and are now quite naturalised in Europe. A more splendid species than the common one has been subsequently discovered in the Bay of Honduras. The *Guinea-fowl* is originally a native of Africa, where it lives in large flocks, in the neighbourhood of marshes. Its noisy and querulous disposition renders it troublesome in poultry-yards, although its flesh is excellent.

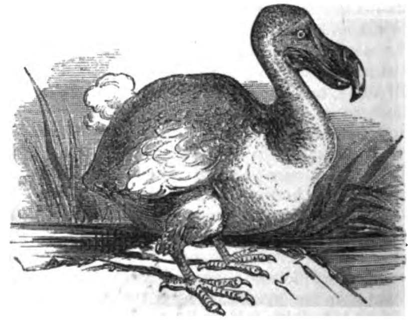
With this family must be classed a genus of birds recently discovered in Australia, and named *Megapodidæ*, on account of the size of their feet. These birds equal the turkey in size, are adorned with a crest, and have strong rasorial claws. According to Mr Gould, they do not incubate, but deposit their eggs in mounds composed of earth and vegetable matter, and by the natural heat engendered in these masses the eggs are hatched.

The *Curassows* (*Cracidæ*), which are restricted to America, are distinguished by the hind-toe being so much developed as to give some power of perching. They offer a remarkable contrast, in their plain colours, to the brilliant plumage of the Asiatic races, which occur in nearly the same parallels of latitude. They are equally capable of domestication with the fowls; and their flesh is of excellent quality. The *Curassows* are about the size of a turkey, and are handsome birds, having the head adorned with crests of long, narrow, erectable feathers, curled at the tips. They commonly perch upon trees. The *Guans* are still more arboreal in their habits. So many varieties of colour are found among them, that it is difficult to trace the limits of the different species. The *Hoazin* is a South American bird, which derives its subsistence almost exclusively from foliage, and chiefly from the leaves of a species of arum growing in marshy places. The toes, unlike those of all other gallinaceous birds, are destitute of any connecting membrane.

The *Tetraonidæ* (Partridge or Grouse tribe) are all of them wild birds, inhabiting uncultivated grounds in the colder climates of Europe, Asia, and North America. They are distinguished by a short hind-toe, a short tail, and comparatively dull plumage. The grouse, black-cock, and ptarmigan, abound in the Highlands of Scotland; and as the objects of a favourite amusement, give a value to much ground which would otherwise be nearly useless. They feed chiefly on the seeds of wild-plants. The largest species of grouse is the *Capercailzie*, or *Cock of the Woods*, once abundant in Scotland, and still so in Norway. It feeds on pine-shoots, and grows to the size of a turkey. Nearly all the grouse have the toes and legs more or less covered with soft feathers—a character which disappears in the *Partridges*, an extensive group, scattered in nearly all parts of the Old World, but unknown in the New. In the *Quails*, we have the miniature resemblance of partridges, but the tail is so short as to be nearly imperceptible. There is in tropical America a singular race of birds, called *Tinamous* by the Brazilians; they have scarcely any tail; the body is thick, and the whole appearance reminds us of a pigmy bustard. These birds live among herbage, and feed upon fruits and insects. Their flesh forms an excellent article of food.

The family of *Columbidæ*, containing a large number of elegant and lovely birds, appears much isolated from the rest, being rather adapted for perching than for scraping. Although it is particularly numerous, and spread over every part of the world, there is no difficulty in distinguishing its members from all other birds. One of their chief peculiarities is the *double* dilatation of the crop, which expands on each side of the gullet; and the young are fed with grain disgorged from this receptacle by the parent, and impregnated with a secretion which it forms. These birds live invariably in pairs; they nestle in trees or in the holes of rocks, and lay but few eggs, though they breed often. This family includes the whole of the well-known tribe of *Pigeons* and *Doves*. Some of the tropical species are of considerable size, and of very rich plumage. The *Common Dovecot-pigeon* is probably derived from the *Rock-pigeon*, which naturally breeds principally among the sea-cliffs, and but sparingly inland. But the *Ringed-pigeon* is of a different stock; and though it chiefly frequents the districts cultivated by man, it resists his nearer approach. The *Carrier-pigeon* is not a distinct species, but only a variety of the common one which has undergone a particular training; and it is probable that other varieties might be similarly trained.

It is proper here to notice an extinct species of fowl which has attracted much of the attention of naturalists,



Supposed form of the Dodo.

and is now believed to have been allied to the pigeon tribe. The *Dodo* existed in the island of Mauritius till

the time of Charles II., and we only know of it now from the descriptions of voyagers, and certain fragments which have happened to be preserved. It was a bulky bird, of heavy figure, with imperfect wings, and only a small bunch of feathers in the usual situation of the tail; a large, strong, curved beak; and legs and feet like those of a turkey. It is supposed to have been particularly adapted to feed on the nuts and seeds of the great forests in which it lived. Mr Strickland considers it as having been, in its mature form, very much like what other birds are in their early state—as it were 'a permanent nestling, covered with down instead of feathers, and with the wings and tail so short, as to be utterly unsubservient to flight.'

Raptores.

In strong contrast to the gentle and vegetable-feeding rasorial tribes is the ORDER RAPTORES, birds designed to subsist entirely on the weaker animals of their own and other tribes, and therefore generally large and powerful, with a formidable armature, consisting of a strong hooked beak, and talons more or less retractile. Such of this order as are designed to catch living prey, are also of great strength and swiftness of flight. Contrary to the usual rule, the female is larger than the male. The raptorial tribes, as compared with others, are not numerous, either as species or individuals; they form pairs, live solitarily, and do not breed large families. They may be arranged in three groups—the Falcons, Vultures, and Owls.

The *Falconidæ* (Falcon tribe) exhibit the perfection of the order, and correspond very closely in their general habits, and the adaptations of structure, with the feline tribe among the Carnivora. Their bodies are of moderate size; their forms light but powerful; their flight graceful; and their courage very great. They are technically distinguished from the vultures by a notch or tooth on the upper mandible, and by the acuteness and strong curve of their talons, which, like those of the cat tribe, are retractile. The members of this family are almost universally diffused over the earth's surface, some species of them existing wherever there is a sufficient expanse of land to supply them with food. Their plumage is destitute of a bright or gay assemblage of colours, but is nevertheless in many instances peculiarly elegant. The plumage of the young bird, however, is very different from that of the adult, which it is long in attaining; and when first hatched, the young falcon, like a new-born kitten, is blind and feeble.

The *Falconidæ* have been commonly divided into the *Noble* and *Ignoble;* the latter not being susceptible of training to the once noble sport of falconry. The Noble division comprehends the *Falcons Proper*, which are distinguished from the rest by the size of the tooth on the mandible, and by the power of their wings, which are long and pointed. They are the most courageous of all the family in proportion to their size, and are specially adapted to pursue and bring down their prey on the wing. From the peculiar construction of their wings, it is not easy for them to rise directly into the air; and their forward flight, in a calm state of the atmosphere, is very oblique. When they wish to rise directly, they fly against the wind, which raises them as it would a paper-kite. A large number of species are known in Europe. The Ignoble falcons have less powerful wings, which are shaped like those of the true falcons, with the tips obliquely cut off; the tooth on the bill is less strongly marked, and is often reduced to a mere festoon.

The *Eagles* may probably be considered as ranking next to the falcons. They are the largest and most powerful of the whole group, and pursue and destroy quadrupeds as well as birds. They are distinguished from all other Raptores by having the legs and feet feathered quite down to the toes. They usually build their nests in lofty and secluded situations, especially among mountains and precipices, and resist with great courage any attack upon their young. A large number

Golden Eagle.

of species, varying considerably in size, exist in Europe, and many others in America. Some of the English ones are no larger than the buzzards, which are nearly allied to them, and may be regarded in their habits, as in their size, as eagles in miniature. They reside in forests, building high in trees, and descending from the top upon their prey. They destroy much game, and are an especial pest to rabbit-warrens.

The *Hawks* are also nearly allied to the falcons, and some of them have been employed in pursuit of game, upon which, however, they stoop obliquely, and not perpendicularly. The tooth on the bill is reduced to a kind of festoon, towards the middle of its margin, but the shape of the bill, in other respects, is the same as in the falcons, being short, high, and curved from the base; the wings are also more rounded, but not so much cut at the ends as those of the eagles. The *Kites* have comparatively short feet and feeble claws, and they are much less courageous than the rest of the family. They are distinguished by their long wings and forked tail, by which their flight is rendered swift and easy, but it is less powerful than that of other Raptores. The common kite of this country has the power of hovering, balanced on its wings, for a longer time than any other known bird. It principally feeds on reptiles.

A few species of this family—mostly included among the *Ospreys* and *Ernes*, both of which, but especially the last, are nearly allied to the eagle—are aquatic in their habits, living upon the sea-shore, and subsisting chiefly or exclusively upon fish. They are at once distinguished by the roughness of the under surface of the foot, which assists them in holding their slippery prey; and the Ospreys are also able to turn backwards the outer toe, and oppose it to the rest, so as much to increase the grasping power of the foot.

The Genus *Circina* (Harriers) have a facial ruff, the feathers of which approach in structure to those of the owls. Three species are found in Britain—the Ring-tailed Harrier, Montagu's Harrier, and the Moor or Marsh Harrier.

Family *Strigidæ* (Owls) fulfil during the night the same office which the bolder hunting-falcons perform in the open day, and serve to keep in check the numbers of

those small mammals to which nature has also allotted a nightly season. They also take birds from their nests, or snatch them from their roosting-place. For their mode of life, which is chiefly nocturnal, their organs are perfectly adapted. Their eyes are so formed as to perceive an object even amidst the gloom of night; their ears are calculated to collect and concentrate the faintest undulations of sound; and their wings are constructed for a noiseless flight, so that they steal unheard upon their prey. In the daytime, they occupy the dark recesses of the forest, wooded rocks, and ivy-mantled towers. Owls, in ancient times, from their appearance of imperturbable gravity, were regarded by some as the emblems of Wisdom. The Egyptians represented Minerva under the form of an owl; and the coin of the Athenians, who considered themselves under the especial protection of that goddess, was stamped with its image. This family consists of only one genus, *Strix*, which is usually divided into two sections—Horned or Eared Owls, and Smooth-headed Owls; the former having a tuft of long feathers on each side of the forehead, and the latter being destitute of those appendages.

The *Great Eagle Owl* (*S. bubo*) furnishes an example of the Horned Owl. It is the largest of the tribe, being nearly two feet in length, and from five to six in the expanse of its wings. It is chiefly an inhabitant of the mountainous districts of Northern Europe, but is seldom seen in Britain. It is destructive to grouse, hares, and fawns. This species builds on rocks or on lofty trees.

Of the Smooth-headed species, the *Barn Owl* (*S. flammea*) may be given as an example. It is more common in this country than any other kind of owl. Its food consists chiefly of mice and small birds, which it swallows whole, without any attempt to tear them in pieces with its claws. The bones and other indigestible parts are afterwards disgorged in small pellets.

Barn Owl.

Family *Vulturidæ* (Vultures) are characterised by a long, straight, and slender beak, curved only at the extremity, and by having a greater or less proportion of the head and sometimes of the neck denuded of feathers. The power of their claws does not correspond with the bulk of their body. Their food consists chiefly of dead carcasses and offal, with which they often gorge themselves to such a degree that they are reduced to a state of stupidity. In hot latitudes, where they chiefly abound, they are of great service in consuming putrefying bodies, which would otherwise infect the air, and spread pestilence in the neighbourhood. No sooner is an animal dead, than its carcass is surrounded by numbers of these birds, which suddenly appear, coming from all quarters, in situations where not one had just before been seen. In some towns of America, they are kept in the market-places, to devour and clear away the offal; and in India, penalties are inflicted on their disturbers.

This family consists of five genera—Gypætus, Vulture Proper, Sarcoramphus, Gypogéranus, and Percnopterus, severally represented by the Lamb Vulture, the Griffon, the Condor, the Secretary Vulture, and the Neophron, which are the only species we shall notice.

The *Lamb Vulture* (*Gypætus barbatus*), or *Bearded Vulture*, the largest of the European birds of prey, measures upwards of four feet from beak to tail, and nine or ten feet in the expanse of its wings. This species, which is the *Lammergeyer* of the Swiss and German Alps, closely resembles the eagle in appearance as well as habits. It has the same confident and upright bearing, and it seeks a living prey as readily as carrion.

Lammergeyer.

The *Griffon* (*Golden Vulture*, or *V. cinereus*) is common in the Alps and Pyrenees, and species of it are found in all the mountainous regions of Africa and of Southern Asia. It nearly equals the Lamb Vulture in size, and is similar to it in habits.

Sarcoramphus (the Condor), the king of the vulture tribe, is peculiar to the Andes. The extent of its wings when expanded is from ten to twelve feet. Borne on these wide-spread pinions, the *Condor* ascends higher than any other bird, being sometimes found at an elevation of 10,000 or 15,000 feet above the level of the ocean.

Secretary.

Gypogéranus (the Common Secretary Vulture), in the

lengthening of its legs and neck, together with its short and strong talons, presents a conformation adapted to destroy and devour poisonous reptiles, upon which it chiefly subsists, although it does not reject lizards or insects. Species of this vulture inhabit the Cape of Good Hope, the Gambia Coast, and the Philippine Islands. It has been called the *Secretary* from the feathers at its ear presenting the appearance of a pen.

The *Neophron Percnopterus* is common in the northern parts of Africa. In Egypt, it is called by Europeans *Pharaoh's Hen.* The species of this vulture, which are of comparatively small size, subsist entirely upon carrion.

Inseasores.

ORDER INSESSORES (*Perching-birds*) comprehends an immense number of species, which spend a large portion of their time on the wing, but at intervals rest on trees or elsewhere, possessing therefore short and slender legs, with feet fitted generally by three long fore-claws, and a hind one to clasp any slender object. They are, generally speaking, mixed feeders; some, however, being more given to animal food than others, and furnished accordingly with bills and claws more allied to those of the Raptores. Many are distinguished by their finely coloured plumage; others, by their powers of singing; and there are some which display a surprising sagacity, with singular powers of imitation. As a rule, the females are smaller, less brilliant in plumage, and less melodious than the males.

The Perching-birds are divided into four groups, each distinguished by some noted external feature connected with their habits.

Group *Conirostres*, so called from having a simple conical beak, may be considered as typical of the order, being the most miscellaneous feeders. Their feet, moreover, are adapted for the greatest variety of purposes, being equally well fitted for walking the ground as for grasping the branches of trees. The group is constituted of five families—Crows, Starlings, Finches, Hornbills, and Crossbills.

Family *Corvidæ.*—Of this, the *Common Crows* are the most characteristic examples, as they combine the general characters of the class in a greater degree than any other birds. In every climate habitable by man these birds are found; they are constructed for powerful and continued flight, as well as for walking firmly upon the earth; they feed indiscriminately on animals or vegetables, and when pressed by hunger, do not refuse carrion; their smell is remarkably acute. They are bold but wary, live in common societies, and possess great courage: when domesticated, they possess a power of imitating the human voice nearly equal to that of the parrot; and, like it, shew signs of greater intelligence than is found in the rest of the class. Under the general term *Crow* are included the *Raven*, which is the largest of European perching-birds, and which is bold enough occasionally to carry off poultry; the *Corby Crow*, which is very destructive to eggs and young game; the *Rook*, which chiefly feeds on insects, and especially devours the grubs of the coleoptera, though it occasionally eats grain if its proper food be scarce; the *Hooded Crow*, which feeds upon mollusks, &c., on the sea-shore; and the *Jackdaw.* The last is a familiar bird, inhabiting deserted buildings, steeples, and high towers, and easily tamed, but troublesome on account of its propensity to secrete any small article of value that comes in its way. The *Magpies* are nearly allied to the Crows; as are also the *Jays*, which live principally, however, in woods, and feed on acorns, &c. The *Nutcrackers* also belong to this family; their habits in many respects resemble those of the woodpeckers; they climb trees, and perforate their bark, and devour all sorts of fruits and insects, as well as small birds.

The *Sturnidæ* are best known by the *European Starling;* the family seems like a smaller race of crows, which they nearly resemble in manners and structure, while much weaker. They seek their food generally upon the ground, are social in their habits, and seem to prefer plains frequented by cattle, on the parasites of which animals they love to feed. They are easily tamed, and may be taught to speak, or to imitate the song of other birds. A great number of species, in different parts of the world, are referred to this family; amongst them may be specially noticed the *Icterinæ*, or *Hangnests* of South America, which build long purse-shaped nests, suspended from the slender branches of lofty trees, in order, as is understood, to save their young from becoming the prey of serpents; they feed on fruits and beetles, and are never seen upon the ground. The African *Buphaga*, or *Ox-pecker*, is also remarkable for its habit of perching upon the backs of cattle, to which it clings by its sharp claws, compressing the skin, to force out the larvæ of gadflies, &c., on which it feeds.

The *Fringillidæ* (Finches) are the smallest of this group of Perching-birds, and are readily known by the shortness and strength of their conical bills. They subsist generally on grain. The number of species is very great; and some among them are everywhere diffused. The *Sparrow*, for example, is in this country found wherever there is a human habitation, generally building its nest under our eaves, and feeding either upon our grain-fields, or on the crumbs that fall from our tables. The Chaffinches, Linnets, Goldfinches, Bullfinches, and

Goldfinch.

Larks, are other species of the Fringillidæ well known in this country. To the same genus with the linnet belongs the *Canary-bird*, originally brought from the Canary Islands, but now so abundantly bred in captivity, that it is difficult to assign the original colour from the numerous varieties that present themselves. The *Chaffinch* is a bird of cold climates: one species, known as the *Brambling*, visits Britain only in the winter; and another nestles in the high Alps, and descends only in the depth of winter to the secondary ranges. To this family belong the *Weaver-birds* of tropical climates, which are celebrated for the remarkable construction of their nests, composed of blades of grass interwoven together; in one species, a number of individuals unite their nests into a large single mass, divided into numerous compartments. The *Whidas*, or *Widow-birds*, resemble the linnets; but have a remarkable development of feathers in the tail at the breeding-season, being destitute of it at other times. The *Grosbeaks*, of which one British species is known as the *Greenfinch*, are remarkable for the thickness of their beaks, which are exactly conical, and with which they pick out the kernels on which they feed. The *Virginian Nightingale* is nearly allied to the grosbeak. To this family also belong the *Buntings*, granivorous birds, of which several species have been seen in Britain; and the *Larks*, so well known for their habit of continuing their song whilst ascending to great heights in the air. With the exception

of one species, these last are peculiar to the Eastern Hemisphere. The hind-toe, and the claw which terminates it, are greatly prolonged; the feet are altogether formed for walking on the ground, where, indeed, these birds construct their nests.

The *Buceridæ* (Hornbills) are birds of the Old World, resembling crows in most respects, but distinguished by the peculiarity from which they take their name—namely, a huge excrescence upon the upper beak, not solid, except in one species, but composed of a fragile net-work of bony fibres. The use of this curious appendage is unknown.

The *Loxiadæ* (Crossbills) are distinguished by a strong curvature of the mandibles, causing their tips to pass each other—a peculiarity which gives them a great advantage in extracting their favourite food, the seeds of the pine-cones.

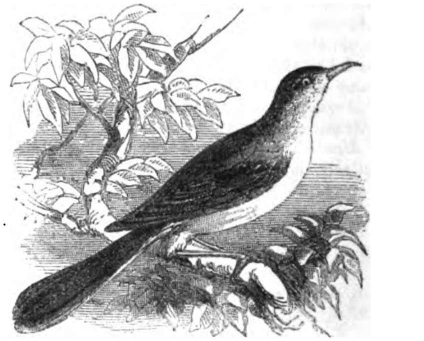
Group *Dentirostres* embraces an extensive variety of genera, all characterised by their more or less carnivorous habits, and the presence of a notch, called a tooth, upon the upper mandible, designed to serve for killing—the peculiarity from which the name of the group is derived. The mouth is, moreover, protected on each side by bristles, which defend the soft parts during the struggles of the prey. The group is divided into five families—Shrikes, Fly-catchers, Thrushes, Warblers, and Chatterers; the first two of which are the most addicted to preying habits, while the last are comparatively vegetable feeders.

The *Shrikes*, *Laniadæ* (from *lanius*, a butcher), are the typical family of the *Dentirostres*. They kill their prey, which consists chiefly of small birds, mice, shrews, and frogs, by repeated blows of the bill on the head; and after satisfying their hunger, they hang up what remains on a thorn, to be devoured at their leisure. From this habit, they have obtained the name of *Butcher-bird*. They are about the size of a black-bird, are gregarious in their habits, and their flight is irregular and precipitate.

The *Fly-catchers*, *Todidæ*, or *Muscicapidæ* (from *musca*, a fly, and *capio*, I take), are characterised by a depressed beak, armed with bristles at the base. They are generally migratory, as all fly-catchers must be, to obtain their food. The two following species only are recognised as visiting Britain:—The *Red Fly-catcher* or *Red Finch* (*M. atricapilla*) visits England in the summer months. Its length is about five inches, and the extent of its wings eight. The *Gray-spotted Fly-catcher* (*M. grisola*) is common enough in England, but rarely visits Scotland. This species arrives early in May, and frequents plantations, orchards, and gardens. When watching for its prey, it sits on one of the outer branches of a tree, from which it descends upon a passing insect, regaining immediately its station.

Of the *Thrushes* (*Merulidæ*), the *Black-bird* (*Turdus merula*) may serve as the type; it is about eleven inches in length. Its food consists of fruit, insects, and caterpillars. The male Black-bird has a glossy black plumage, while the upper part of the body of the female is of a blackish brown; the bill being of an orange-yellow colour, and the feet brown. This beautiful and well-known songster is among the first to welcome the return of spring.

The *Common Thrush* (Mavis or Song-thrush) and *Fieldfare* are also well known and characteristic examples. These, as well as the *Missel-thrush*, *Red-wing*, *Ring-thrush*, &c., are closely allied species of the same genus, of which the other species are distributed over the whole globe. The *Mocking-birds*, on the other hand, which probably stand unrivalled for their powers of voice, and have the singular gift of imitating the cries of many other birds, are restricted to America: some of them approximate to the shrikes in their habits. The *Orioles* are also nearly allied to the thrushes; they are migratory birds, having longer wings than their congeners, and chiefly frequent the south of Europe, where they build very curious hanging-nests. A few



Mocking-bird.

species of this family have somewhat aquatic habits. One of these is the *Dipper*, or *Water-ousel*, which immerses its whole body without swimming, and walks about in a jerking, fluttering manner at the bottom of streams, in search of the small animals which constitute its food.

The *Warblers* (*Sylviadæ*) are the most musical of European birds, but are inferior to many others in the brightness of their colours. Those best known are the Nightingale, the Redbreast, and the Willow Wren.

The *Nightingale* (*Sylvia luscinia*) is a migratory bird, which visits England in the beginning of April, and leaves it in August, rarely getting so far north as Scotland. It builds on trees, and does not sing till the young ones are hatched. The notes which it then gives forth have in all ages been a theme of admiration. 'To hear it on one of those balmy mornings in May, when every leaf is freshness and every breath young perfume, is worth more than a whole musical festival.' The Nightingale is the largest of the Warblers, its length being about seven inches, and the extent of its wings ten or eleven inches.

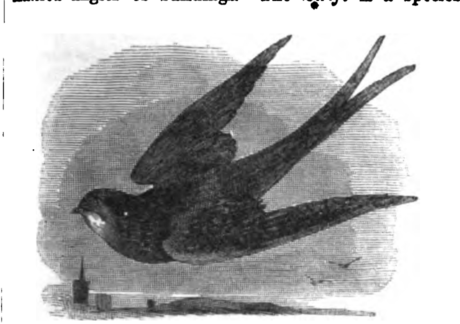
The *Robin* (*S. rubecula*) is a constant inhabitant of Britain, and the greater part of the European continent. It is a beautiful little bird, and has a sweet song. It is useful in gardens and orchards, as its food consists principally of worms and caterpillars. In summer it is shy, but in winter it draws near the abodes of man. The *Wagtail* (*Motacilla*) is another member of this family which attracts general attention, on account of the habit from which it derives its name, and its sprightly movements, as it flits about searching for insects near shallow waters.

The *Chatterers*, *Ampelidæ* (ἄμπελος, a vine), are characterised by a straight convex beak, and an uncommon width of gape. The *Bohemian Chatterer*, or *Wax-wing*, is a species well known in Europe, Asia, and America. It is less than a thrush, and is crested on the head. Its general colour is a vinish gray, with a black throat.

The group *Fissirostres* derive that name from having the beak deeply cleft—a peculiarity which gives a wide gape, and fits these birds for catching insects on the wing. Some have the outer toe nearly as long as the middle one, and were hence called by Cuvier *Syndactyli*.

The family *Hirundinidæ* (Swallows) are well-known summer visitors of the British Islands, Africa being understood to be their chief winter resort. They are remarkable for being so much on the wing in search of food, and for their vivid, irregular movements in flying. The hind-toe is directed very much forward, and all the four are armed with strong claws, giving

the animal the power of clinging to the faces of perpendicular rocks and buildings. The *Martin* is a familiar bird, building a curious mud-nest in the sheltered angles of buildings. The *Swift* is a species



Swift.

possessing more enduring powers of flight than the swallow, which is often seen on its long journeys to fall wearied upon the surface of the sea. In the Indian Archipelago is a small species of swallow, which forms its nest of a kind of sea-weed, which it macerates in its stomach, and arranges in layers. These nests are used in China to make a kind of soup, much prized as a delicacy.

The *Goat-suckers*, or *Night Jars* (*Caprimulgidæ*), fly in the dusk, and feed on moths and beetles, which they seize on the wing. Like the owls, they cannot bear the glare of day. In Britain, we have only one species, which visits in the beginning of summer, and leaves us in the end of September. It is chiefly found on furze of commons, wild bushy heaths, and broken hilly ground,

Goat-sucker.

covered with ferns, especially in the neighbourhood of thickets and woods. It is about eleven inches in length, and twenty-three in the expanse of its wings. It derives its name from the absurd belief of the ancients, that it injured the teats of goats in its attempts to suck them.

The *Bee-eaters* (*Meropidæ*) are said to be extensively distributed in Africa, where they migrate in small flocks to the countries along the northern shores of the Mediterranean. They feed on insects, especially bees, which they pursue much in the manner of swallows. To this family also belong the *Rollers*, most of which are natives of the East, but of which one species inhabits Europe. They are in some respects intermediate between the swallows and bee-eaters. One species is stated to perch and watch for prey on the horn of the rhinoceros, giving notice to that animal of the approach of the hunter.

The *King-fishers* (*Halcyonidæ*) are generally natives of the warmer regions of the globe. They live upon aquatic insects and small fish, and may be seen perching on the stump of some decayed tree which overhangs a stream, watching the minnows, on which they dart with

King-fisher.

unerring aim. They then return to their perch, beat their victim to death, and swallow it. The only species indigenous to Britain is a beautiful little bird, rather larger than the lark. The *Todies* (*Todidæ*) are small American birds, nearly allied to the former family.

The group of *Climbing-birds* (*Scansores*) comprehends four families of considerably diverse character, but having one remarkable peculiarity in common—namely, an arrangement of the toes, by which two are directed forward and two backward, so as to fit the bird especially for climbing. They are not good walkers or fliers, and, careless of nest-building, are content to rear their young in the hollows of trees. It may be said that of all birds they are the most arboreal.

Family *Picidæ* (Woodpeckers).—This kind of bird is well fitted for climbing trees, not only by its *zygodactyle* feet, but by the pointed feathers of its tail, which, being inserted in the bark, form a rest for it as it ascends. It is furnished with a long sharp tongue, which it inserts into the chinks of timber in search of insects, transfixing them with its barbed point, and further securing them by means of a viscid substance with which it is covered. At the pairing-season, the Woodpecker communicates with its mate, not by song, as is customary, but by rattling its beak against a dead-branch; from which sound its name has been derived. There are three species constantly resident in Britain—the Green Woodpecker, the Great-spotted Woodpecker, and the Lesser-spotted Woodpecker. The first is sometimes called the *Rain-bird*, because it makes more noise than usual before wet weather. This bird is about thirteen inches in length, and twenty-one in breadth.

The *Wryneck* (*Yunx torquilla*) belongs to this family. In England it is called the *Cuckoo's Messenger*, because it arrives only two or three days before that bird. Its food consists chiefly of ants. A hole in a tree is generally chosen for nestling.

The *Creepers* (*Certhiadæ*).—Of these birds, the *Nuthatch* is the only species known in Europe. It is frequently seen during the day running rapidly about, either up or down the trunk or branches of a lofty oak or beech tree. The food of the Nuthatch consists of insects and seeds, also acorns and nuts. It procures a supply of insects, such as earwigs and caterpillars, from beneath the old bark of trees, by lifting it up with its wedge-shaped bill. It is remarkable for its instinct in fixing a nut in a chink, while it pierces it with its bill, swinging the whole body as on a pivot to give effect to each stroke.

The *Cuckoos* (*Cuculidæ*).—The *Common Cuckoo* (*Cuculus canorus*) is the type. It is a migratory bird, arriving in this country about the end of April. Its cry, 'cuckoo,' from which it derives its name, is well known. In size, the bird is nearly equal to a pigeon, and is of an ash-gray colour. Its food consists of caterpillars,

insects, and small fruit. The Cuckoo has no nest of its own, nor does it hatch its own eggs, but deposits them

Cuckoo.

in the nests of other birds, such as the Hedge-sparrow, by which they are reared; and as it deposits but one egg in each nest, the process of rearing the progeny may be carried on by several foster-parents at once. In its flight, it is usually attended by small birds, chiefly the Meadow-pipits.

The *Toucans* (*Ramphastidæ*) have bills of enormous size, nearly as large as the body itself. They are gregarious in their habits. Their food consists of fruit and insects, and the eggs and young of other birds. In feeding, they throw each morsel into the air, and catch it in its descent. This family is peculiar to the warm regions of America. They are in general black, with lively colours on the throat, breast, and croup.

The *Psittacidæ* (Parrots) constitute a family which is very widely diffused through the torrid zone in both new and old continents, and is scarcely found beyond it. It contains a large number of species, each of which has its peculiar locality, the short wings of these birds not enabling them to traverse large tracts of sea. They correspond with the other *Scansores* in little else than the structure of the foot, and this is formed rather for grasping than for climbing. It is also used for conveying food to the mouth, a peculiarity nowhere else seen but in the goat-suckers. Their beak is stout, hard, and solid, curved and pointed very much as in the diurnal birds of prey. Their jaws are set in motion by a greater variety of muscles than are found in other birds. The tongue is thick, fleshy, and rounded; and the larynx, or organ of voice, is also more complicated—by which peculiarities they gain their facility of imitating the human voice as well as other sounds. Their voice in a state of nature, however, is loud and harsh. They use their crooked bills in clambering up trees, and nestle in hollow trunks. They subsist upon the succulent parts of vegetables, especially bulbs and fruits. They are distinguished from the rest of the scansorial birds by their intelligence and docility—qualities in which some species are unsurpassed by any members of the class.

The *Parrot tribe*, nearly all of which are adorned with gorgeous colours, has been divided, chiefly from a regard to peculiarities of plumage, into many minor groups, the limits of which, however, are mostly arbitrary. The *True Parrots* are square-tailed, and have no crests. They are found in both the old and new continents, and are more easily taught to speak than others of the family. The *Cockatoos* are also square-tailed, but have crests upon their heads. The white ones inhabit the Indian Archipelago and Australia; they are singularly gentle and affectionate, and easily maintained in captivity in Europe. The *Love-birds* are a beautiful group, found in both continents, nearly allied to the parrots, but of diminutive size. The *Parroquets* have a long-pointed tail, and chiefly inhabit the Asiatic continent and islands, and Australia. An American species of Parroquet is the only member of the parrot tribe found to the northward of the Tropic of Cancer. The *Macaws* are long-tailed American species, which exceed all the rest in size, and are superbly coloured. The *Loris*

Cockatoos.

are Oriental species, with square tails and dense soft plumage, the colours of which are glowing in the highest degree; the beak is in general comparatively feeble, and they feed upon the juices of flowers and the pulp of the softest fruits.

The group TENUIROSTRES (Slender-billed Birds) are generally of small size and great beauty of plumage, chiefly confined to tropical countries. By their slender beaks and long tongue, forked or divided into filaments at the extremity, they are specially fitted to live upon the juices of flowers; in which respect, as well as in their fine colouring, they remind us of certain families of insects. Many of them, however, are also insectivorous. The feet are very short and delicate.

The *Meliphagidæ* (Honey-suckers) are distinguished by their notched bill; their tongue is terminated by a bunch of delicate filaments; and the hind-toe is so strong and robust, that it serves as a support to the bird during the process of feeding. This group is chiefly confined to Australia, where its members abound in great variety of form, and where they find a never-failing support in the luxuriant vegetation of that country.

The *Paradisidæ* (Birds of Paradise) are among the largest of the *Tenuirostres*, and seem to live, like the

Bird of Paradise.

rest of the order, chiefly upon soft vegetable substances. They are confined to New Guinea and the neighbouring

islands; and for a long time no specimens were obtained but such as had been deprived by the natives of their legs, whence it was at one time supposed that they were destitute of limbs, and supported themselves entirely on their airy plumes. The extraordinary development of their feathery appendages is well known; but of the purpose these serve in their economy, no plausible account has been given. The very restricted locality of these birds, and the savageness of the people who inhabit it, have prevented naturalists from obtaining much knowledge of their habits. They are partly supported upon insects.

The *Trochilidæ* (Humming-bird tribe), so celebrated for the metallic lustre of their plumage, and particularly for the gem-like brilliancy of some of their feathers, have within their long slender beak a tongue divided almost to the base into two filaments or threads. These filaments are *not* tubular, as sometimes described, but flattened. The organ is employed for diving into flowers and sucking their juices; but it is not improbable that it also serves for catching insects, since it is unquestionable that, like others of the order, the Humming-birds are partly insectivorous. When hovering over flowers, these birds balance themselves in the air by a rapid motion of the wings, and it is by this movement that the *humming* sound is produced from which they take their name. The flight of these birds, the smallest of the order, is so rapid as frequently to elude the eye. They live solitarily; defend their nests with courage, attacking with their needle-like bills the eyes of intruders, which makes these minute creatures truly formidable; and they fight with each other desperately.

This family is exclusively confined to America, and, with few exceptions, to the southern part of that continent and the adjacent West Indian islands. More than 170 species are at present known, and others are constantly being discovered. The smallest of them, when plucked, is less than a large humble-bee; and one only, which is much larger than any others as yet known, nearly equals the common swift in size.

The *Cinnyridæ* (Sun-birds) represent the Humming-birds in the eastern continent. They are closely allied to the *Trochilidæ* in general structure, and in the mode of obtaining their food, but their tongue is not so deeply divided. They are small birds, and the males have the most brilliant colours, rivalling those of the humming-birds during the breeding season; but the garb of the female, and of the male at other parts of the year, is much more dull. The bill is not so straight as in the Trochilidæ, and the legs less delicate, so that a connection between that and other families is evident through this one. The *Sun-birds* are of a lively disposition, and sing agreeably.

Hoopoe.

The *Promeropidæ* (Hoopoes) are also restricted to the Old World; one species, the *Common Hoopoe*, annually visits Europe in company with the Bee-eaters, and other swallow-like birds; but, unlike its congeners, it seeks its food on the ground. Most of the tribe, however, feed upon the juices of flowers and succulent fruits, and their plumage possesses metallic lustre. The feet, as well as the tongue, are very short.

CLASS MAMMALIA, OR SUCK-GIVING ANIMALS.

The MAMMALIA agree with birds in possessing a complete double circulation and warm blood; and with reptiles in breathing air, and generally living on the surface of the earth; but they differ from all other vertebrata, not so much in producing their young alive (which is the case in a few species of reptiles and fishes), as in their subsequent nourishment of them by suckling—from which circumstance the name is derived. This class is placed at the head of the Animal Kingdom, not only as being the one to which Man belongs, but also because it is that which enjoys the most numerous faculties, the most delicate sensations, the most varied powers of motion; and in which all the different faculties seem combined to produce a more perfect degree of intelligence; the one most fertile in resources, most susceptible of perfection, and least the slave of instinct. Although principally adapted to motion on the ground, we find one tribe possessed of the power of rising into the air like birds, and another formed to inhabit the water like fishes; but both these agree with other Mammalia in all essential characters, and differ very widely from the classes with which their habits seem to associate them. To the Mammalia is confined the protection of the body by hair or fur; the nearest approach to it being in the hair-like feathers of a few species of birds. But the presence of this covering is by no means universal in the Mammalia.

Naturalists, in seeking to classify the Mammalia, have to look chiefly to those indications which the teeth, extremities, and other external characters furnish, regarding the general habits and dispositions of the several animals. Thus, keeping out of view minor distinctions, the possession of sharp fangs and claws is a clear mark of carnivorous habits; flat-topped teeth and hoofs, equally a proof of a gentle and herbivorous character. The flapper of the whale shews a fitness for progression in the sea; the development of a wing on the hand of the bat, a design that the animal should make its way through the air. Other distinctions are found in the advance of the animals in their general development, forming still broader grounds of classification.

A minor portion of the Mammalia produce their young in an immature state—indeed scarcely alive—and these attain a comparatively low permanent condition, their bodily structure presenting many points of affinity to birds and reptiles. In this division, which are chiefly localised in Australia, there are two groups.

Monotremata.

The MONOTREMATA—so named because, as in birds, the excretory openings are united into one—are exclusively Australian. There are two species, the *Echidna*, or Spiny Ant-eater, and the *Ornithorhynchus*, or Duck-billed Platypus.

The *Spiny Ant-eater* (*E. hystrix*) is rather larger than the common hedgehog, to which it bears some resemblance, being armed with spines on the upper part of the body, and having a prolonged snout. It frequents sandy places, and burrows in the ground. Its food consists of ants and other insects, which it entraps with its long and adhesive tongue. The Ornithorhynchus derives this name, now universally adopted by naturalists, from the bird-like snout of the animal (ὄρνις, a bird, and ῥύγχος, a beak). 'The similarity of its jaws to those of a bird,' says Swainson, 'is so great, that

upon its first discovery, it was strongly suspected the specimen sent to Europe was a deception, practised by some cunning fellow on the credulity of naturalists by

Ornithorhynchus.

ingrafting the bill of a duck upon the skull of a quadruped.' By the colonists, it is called the Water-mole—an appellation suggested by its aquatic habits, combined with some slight resemblance which it bears to the common European mole. The ornithorhynchus is about eighteen inches in length, and clothed with a dense fur. It frequents the tranquil parts of rivers, in the banks of which it burrows, and it obtains its food by the capture of small aquatic animals.

Marsupialia.

The MARSUPIALIA exhibit a nearer approach to the full mammalian character. The name, signifying Pouched Animals (Lat. *Marsupium*, a purse), is derived from the remarkable provision which is made for the continued nourishment of the young after their immature birth. The new-born imperfect offspring attaches itself to the teats of the parent, and remains fixed there until it has acquired a degree of development comparable to that with which other animals are born. The skin of the abdomen of the parent is so disposed as to form a pouch, in which these imperfect young are protected, and into which, long after they can walk, they retire for shelter on the apprehension of danger. It is remarkable that, notwithstanding the general, and usually very striking, resemblance of the species to each other, they differ as much in the teeth, the digestive organs, and the feet, as do the other orders of Mammalia from each other; and indeed it may be said that some of these other orders are *represented* each by a strongly analogous group, in the Marsupialia.

The geographic range of this order is extremely peculiar. With the exception of the Opossums, which inhabit America, its species are at present almost confined to Australia and the neighbouring countries, where they constitute, with the Monotremata, almost the only mammiferous animals. It is remarkable also, that from the remains found in secondary rocks, they appear to have existed at a much earlier geological period than the superior Mammalia, and to have been more extensively diffused over the earth's surface than at present.

The *Marsupialia* may be divided into the following families, which have been named according to their predominating food. These terms must not, however, be regarded as strictly indicating the food of the several species contained in each group, but only their general tendency to select for their support the substances implied by those designations. 1. *Sarcophaga*, or Flesh-eaters, such as the *Dasyurus*. These have three kinds of teeth,* long canines, and a simple stomach like that of the Carnivora. 2. *Entomophaga*, or Insect-eaters, such as the *Opossum*. These have also three kinds of teeth and a simple stomach, but a more complex intestinal canal: they are parallel with the Insectivora. 3. *Carpophaga*, or Fruit-eaters, as the *Phalangers*, or Flying-opossums. These have large and long incisors in both jaws, the canines sometimes absent, and a more complicated intestinal canal. They may perhaps be regarded as representing the frugivorous Bats. 4. *Poephaga*, or Grass-eaters, as the *Kangaroos*. These have long anterior incisors, the canines only present in the upper jaw, or altogether wanting, and a complex intestinal canal like that of other herbivorous Mammalia. 5. *Rhizophaga*, or Root-eaters, as the *Wombat*. These, in the structure of the teeth and alimentary canal, are true Rodentia.

All the existing species of the first family, *Sarcophaga*, are confined to New Holland and Tasmania. These animals vary in size, from that of a small wolf to that of a mouse. The larger ones possess considerable ferocity, destroying sheep, and even invading houses; others attack poultry, of which they suck the blood; and the smallest are partly insectivorous, and live on trees, thus shewing an approach to the next family. The names *Hyæna*, *Devil*, *Wild-cat*, &c., applied by the colonists to these animals, sufficiently indicate their general correspondence in habit with those of the order Carnivora.

Of the second family, *Entomophaga*, some are adapted to live on the ground, and even to burrow beneath the surface, whilst others ascend trees in search of their food. To this latter group belongs the *Opossum* tribe, which is extensively diffused through America. These have a long and prehensile tail; and the hinder thumbs are long, and effectively opposable to the other digits. They are nocturnal animals, of slow gait, and nestle upon trees, where they pursue birds, insects, &c., without rejecting fruit. The *Virginian Opossum* is

Virginian Opossum.

nearly the size of a cat. It enters the villages at night, and attacks poultry, devouring also their eggs. One species frequents the marshes of the sea-coast, where it feeds chiefly on crabs. In a part of this tribe no pouch exists, but only a vestige of it, in the form of a fold of skin on each side of the abdomen. In these, the mother supports her young by entwining her tail with theirs.

The animals of the third family, *Carpophaga*, are peculiarly adapted to live among the trees on which they seek their food. Some species, in their general form, and in the prehensile character of their tails, approach the opossums. Such are the *Couscous* of the Molucca Islands; these feed on insects and fruit. At the sight of a man, they are said to suspend themselves by the tail; and if he gazes at them steadily for some time, they fall through lassitude. The most remarkable species is the *Petaurus* of New Holland, which much resembles the flying-squirrels. Like these, it possesses an extension of the skin on each side of the body, between the anterior

* The front-teeth are termed incisors, or cutters; those next to the incisors, are canine, or dog-teeth; and those at the sides of the jaws, molars, or grinders.

and posterior legs; and a flattened bushy tail, by the help of which it can take leaps of considerable length. Like the bats, or the flying lemur, to which it may be compared, it is a nocturnal animal, remaining during the day nestled in the hollows of trees; but it becomes animated as night advances, skimming through the air, supported by its lateral expansions, half leaping, half flying from branch to branch, and feeding upon leaves and insects. It would seem that, whilst in motion, it has some power of altering and directing its course. Another animal belonging to this group, the *Phascolarctos*, or *Koala*, a native of New Holland, is as large as a moderate-sized dog. It has the gait and carriage of a young bear, and passes its life upon trees, and in dens or holes which it hollows at their feet. The female carries her young for a long time on her back.

The family of *Poephaga* consists chiefly of the *Kangaroos* and the *Kangaroo-rat*, all of which are inhabitants of New Holland and the neighbouring countries. The Kangaroos are remarkable for the enormous length of their hinder feet, whence their generic name, *Macropus* (long-footed), is derived. The hind-legs and tail are also very largely developed; whilst the fore-legs and feet are very small. From this great inequality in the size of the limbs, they advance on all-fours very slowly; but they can make immense leaps with the hind-legs, the tail probably assisting them. These are furnished with one large nail, almost like a hoof, which is a powerful weapon of offence and defence; for, supporting itself upon one leg and its tail, the animal can inflict a very severe blow with the leg which is at liberty. The largest species is sometimes six feet in height, having the bulk of a sheep, and weighing 140 pounds. Its flesh is used as food by the New Hollanders, and is described as being somewhat like venison. The Kangaroo grazes, like ruminant animals, and is the only inhabitant of New Holland that at all represents that tribe. The young ones reside in the maternal pouch until they are able to graze for themselves, which they effect by stretching out the neck from their domicile while the mother herself is feeding. Several species exist, diminishing in size to less than that of a hare.

Great Kangaroo.

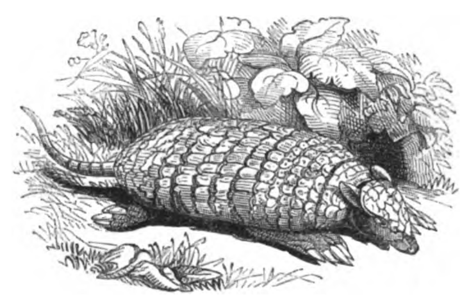
The Kangaroo-rat connects this family with the preceding one; it is about the size of a small rabbit.

The last family, *Rhizophaga*, contains only one species at present known—the *Phascolomys Wombat*. This animal is about the size of a badger, by which name it is known to the colonists, and is a native of Tasmania. It is a sluggish animal, with a flattened head and body. It burrows in the forests and low grounds; hiding itself in natural crevices at higher elevations. When attacked, it grunts like a pig; it bites hard, and is furious when much provoked. As already mentioned, the organisation of its digestive system corresponds closely with that of the Rodentia; and from what is known of its food, it seems to derive support, like the animals of that order, in the tougher kind of vegetable substances.

Another subdivision of the Mammalia is marked by higher characters than the preceding, but still must be placed in a position somewhat below the highest, the animals composing it being generally diminutive and weak, with a lower style of dentition, and less complex brain, than those which are next to be considered. In this division are comprised three orders—*Edentata*, *Insectivora*, and *Rodentia*.

Edentata.

ORDER EDENTATA take their name from the peculiarity common to all, of an entire absence of the incisor teeth. One large group, *Myrmecophaga*, or Ant-eaters, are specially fitted for their insectivorous mode of life, by the long-pointed form of their muzzle and the strength of their feet, the extremities of their toes being nearly included in large nails, which approach in character to hoofs. They are peculiar to the warm and temperate regions of South America. Some species are covered with hair; others with scales, which they elevate when irritated. They possess a long thread-like tongue, always covered with a gluey saliva, and which forms an admirable instrument for catching burrowing insects such as ants. Another group, the *Armadillos*, are remarkable for the dense armour of hard scales



Armadillo.

with which they are covered. They subsist partly on vegetables, and partly on insects and carcasses. This group is also confined to South America. They are generally about the size of a cat, but one species is three feet in length. Ant-eaters and Armadillos are considered, as of all the true viviparous mammalia, approaching, in the structure of their brain, most nearly to birds.

The *Tardigrada*, or Sloths, are a group of animals considerably different from the above in all respects but their want of the fore-teeth. They are herbivorous, inhabiting the forests between Mexico and Brazil, the largest not exceeding a fox in bulk. They live on trees, which they never leave, unless compelled through force or accident; and what is extraordinary, their most common posture is that of suspension from the branches, which they clasp with their arms and legs. In this attitude, they sleep, rest, and move from tree to tree. For this mode of life they are admirably adapted, their arms being twice as long as their hinder extremities; and they are by no means so slow as they are said to have been by early naturalists, who had seen them only in a state of confinement.

Fossil remains of two very large animals of this family have lately been discovered in America—the *Megatherium* and the *Megalonyx*—nearly equalling the elephant in size. From the structure of their teeth, it

has been inferred that they were leaf-eating animals, but with a short neck, unfitting them to reach the highest branches. It is difficult to ascertain the manner in which they got at their food. Professor Owen supposes, that they first cleared away the earth from the roots of a tree with their claws, and then seating themselves on

Sloth.

their hinder extremities, and grasping the trunk with their fore-feet, heaved it to and fro till they prostrated it to the ground, and then regaled themselves on its leaves.

Insectivora.

ORDER INSECTIVORA are small animals, subsisting chiefly on insects and vegetable substances. They are all nocturnal and subterranean in their habits, and most of them spend the winter in a state of sleep. From the shortness of their legs, their movements are necessarily slow. They are divided into three families—*Hedgehogs*, *Moles*, and *Shrews*.

Erinaceadæ (Hedgehogs).—These animals are called Hedgehogs because they prefer the roots of hedges as their hiding-places, and from a superficial resemblance which they bear to pigs. Their teeth shew that they are omnivorous. Nature has provided them with a bristly coat of armour, which by strong cutaneous muscles they can draw over every part of the body, or every part which is accessible, so as effectually to protect themselves from their enemies. They live on fruit and the eggs of small birds, and are torpid in winter.

Talpidæ (Moles) live chiefly under ground, feeding on insects, worms, and roots. Their feet are admirably adapted to their subterranean mode of life. From the smallness of their eyes, which are scarcely perceptible, it was long considered that the Moles were blind; but it is now ascertained that they are by no means deficient in the sense of sight. Moles have no external ears; but, from the tympanum being large, their sense of hearing is nevertheless very acute.

Sorecidæ (Shrews) are small animals, having soft hair. Some of the species are among the smallest of mammalia. The Common Shrew measures only two inches in length. The food of these animals consists of worms and insects. They burrow in the ground, seldom appearing abroad except towards night. This family is composed of *Shrews*, *Amphibious Shrews*, and *Water Shrews*.

Rodentia.

ORDER RODENTIA take their name from their gnawing habits, for which they are fitted by having the two canine teeth close together (incisors being wanting), the pairs in the several jaws working against each other. These teeth are constantly wearing away, but as constantly growing; so that when one is lost or broken, its opposite, having nothing to wear it down, becomes developed to an enormous extent. The body is heavier in the rear than in the foreparts, so that rodent animals leap rather than run.

The *Rodentia* may be divided into seven families, the technical distinctions between which are founded upon minute particulars in the structure of the cranium and of the lower jaw. 1. *Sciuridæ*, or Squirrel tribe, comprehending a large number of light and agile animals, chiefly distinguished by their long bushy tails, and by their adaptation to a residence in trees, and to live upon their produce. 2. *Muridæ*, or Rat tribe. 3. *Castoridæ*, or Beaver tribe, including the Voles, Lemmings, &c. 4. *Hystricidæ*, or Porcupine tribe. 5. *Cavidæ*, or Guinea-pig tribe. 6. *Chinchillidæ*, the Chinchilla tribe. 7. *Leporidæ*, the Hare tribe. The rodents of the fourth, fifth, and seventh families are destitute of the clavicle, which those of the first three and sixth possess.

Squirrel.

Of the family *Sciuridæ*, the *Common Squirrel* of this country may be taken as a characteristic illustration; and its form and habits are sufficiently well known to render particular description unnecessary. It lives entirely upon vegetable food, in search of which it leaps with great agility from branch to branch. In taking these leaps, when it is once thrown off by an effort of its long and powerful hind-legs, it is in a measure sustained by the horizontal spreading of its limbs and bushy tail, the hairs of which are directed laterally, so as to resemble feathers. In the *Pteromys*, or Flying-squirrel, this sustaining power is much increased by an extension of the skin of the flank between the fore and hind legs, which serves as a parachute. The *Marmots* are allied to the squirrels in the number and structure of their teeth, which are partly adapted, however, to insect food. In other respects, they are almost the reverse of squirrels, being heavy, with short limbs and a moderate-sized tail, and living on the ground, or even in burrows beneath it. They are connected with the former tribe, however, by an elegant little animal termed the *Ground-squirrel*, partaking of the habits of both: this is a native of Eastern Europe. A very remarkable kind of Marmot is one known in North America by the name of the *Prairie-dog*, or *Barking-squirrel*, on account of its voice, which resembles the bark of a small dog. It lives in great troops, in immense burrows. More allied to the squirrels in the size of their tail and active habits, but differing in their dentition, are the *Dormice*, the structure of whose teeth shews them to approximate to the next family. They chiefly subsist on vegetable food; but some species of them attack small birds. All the members of this family pass the winter in cold climates in a state of lethargy, which is most profound in the Marmots and Dormice.

The family of *Muridæ* contains the smallest, and at the same time the most prolific, of the Mammalia. No undomesticated animals are better known than *Mice* and *Rats*. The *Brown* (commonly, but erroneously, called the Norway) *Rat* made its first appearance in Paris about the middle of the eighteenth century, and in England not many years earlier. It is believed to have originally come from Persia, where it lives in extensive burrows. It is said to have arrived in Astracan by swimming across the Volga, after an earthquake, in 1727. Its astonishing fecundity, its omnivorous habits, the secrecy of its retreats, and the ingenious devices to which it has recourse, either to retain its existing place of abode, or to migrate to a more favourable situation, all conduce to keep up its almost overwhelming numbers. Where a plentiful supply of animal food is afforded them, rats will feed exclusively upon it. The Brown Rat is now speedily replacing the *Black* or *Old English Rat*, which is becoming rather a rare animal in this country, and which, from its smaller size, is an unequal match for the usurper. There is reason to believe, however, that even this is not a native of England, and that it was introduced from France about the middle of the sixteenth century. From Europe these two rats—which infest vessels equally with houses—have been sent to America, the islands of the Pacific, and many other places, in some of which they have now become a serious inconvenience. The only strictly indigenous British species of Muridæ are the *Harvest-mouse* and *Long-tailed Field-mouse*, both of them very beautiful little animals, and very interesting to the naturalist, although highly injurious to the agriculturist. A great number of species exist in various parts of the world, which do not differ widely from each other.

The *Hamsters* have teeth nearly similar to those of the rats, but their tails, instead of being long and scaly, are short and hairy, and their cheeks are hollowed into pouches, in which they can stow away a large quantity of grain for transport to their nests. They abound in the sandy plains of the north-east of Europe, from Germany to Siberia, and are very injurious, from the quantity of grain they hoard up in their extensive and intricate burrows. They have more ferocity than most of the order, and will attack any animal that comes in their way. They are believed to feed upon birds as well as upon vegetables. Allied to the rats in its dentition, and having also some points of resemblance to dormice, is the curious genus *Dipus*, or Jerboa, the general form of whose body, as well as its mode of progression, is very similar to that of the kangaroo. The enormous length of the hind-feet occasioned them to be designated Two-footed Rats by the ancients; whence their present generic name is derived.

Of the *Castoridæ*, the *Beaver* is probably the type; but this family contains many genera having a close

Beaver.

resemblance to the rats. The Beaver is distinguished from all other rodents by its horizontally flattened tail, which is of a nearly oval form, and covered with scales. The hind-feet are webbed, by means of which and the tail these animals obtain considerable swimming powers. They chiefly subsist on bark and other hard substances, and can fell trees of considerable size, of which they use the bark and twigs as food, employing the stems in the construction of their remarkable habitations. The flattened tail is employed by them as a kind of trowel, with which they plaster the walls of their houses. The Beavers are connected with the previous family by the *Arvicolæ*, or Voles, many of which bear a strong general resemblance to rats, but differ in their dentition. Most of them are partly aquatic in their habits; such is the *Common Water-rat* of this country, the food of which, like that of the Beaver, is (contrary to the general opinion) almost exclusively vegetable. To this group also belong the *Lemmings*, or Scandinavian Rats, which are remarkable for their occasional migrations in immense bodies. They are stated to advance in a straight line, regardless of rivers and mountains; and while no insurmountable obstacle impedes their progress, they devastate the country through which they pass. Most of this family lay up a winter store of food, upon which they subsist in the intervals of sleep, and they do not go abroad during that season.

The animals which are characteristic forms of the family *Hystricidæ*, are recognised at the first glance by the stiff and pointed quills with which they are armed, somewhat similar to those of the hedgehogs, but usually much larger. Besides the *Porcupines* and their allies, however, to which this description more particularly applies, this family contains several forms which connect it with the two preceding. The name porcupine is corrupted from the French *porc-épine*, a term expressive of the pig-like aspect and grunting voice of these animals, as well as of their spiny covering. They live in burrows, and have very much the habits of rabbits. The best known species inhabits the south of Italy, Sicily, and Spain. It is nearly the largest of the Rodentia, measuring almost three feet in length. There is an American genus nearly allied to the true porcupine, which has a long prehensile tail, like that of the opossums, and lives in trees.

Porcupine.

The next family, that of *Cavidæ*, contains the largest sized animals of this order, although, when compared with ordinary quadrupeds, they would be termed small. They are naturally restricted to tropical America, where they replace the hares and rabbits of cold climates. But the *Guinea-pig* is now extremely common in Europe, and is quite domesticated. The *Capybara* is an inhabitant of the sides of nearly all the great rivers of South America, and is the largest known animal of the order, being about three feet in length, and of the size of the Siamese-pig. It has a large, thick, and blunt muzzle, is destitute even of the rudiments of a tail, and is scantily covered with bristly hairs. Its semi-aquatic habits are shewn by the webbing of the feet. By this structure it can both swim and dive with much activity. Upon land

it makes but little progress, running badly, and generally diving in the water to avoid danger. It lives in small societies, and seems to be a nocturnal feeder. Another of the Cavidæ is the *Agouti*, which is an inhabitant of the Antilles and tropical America. It is about the same size as the European hare, and, like it, possesses very long hind-legs, by which it runs, or rather leaps, with considerable swiftness. In regard to its food, however, and its manner of feeding, it rather resembles the squirrel; preferring nuts to herbage, and sitting upon its haunches whilst eating. When angry, it stamps with the fore-feet, grunts like a young pig, and erects the bristly hair of the crupper in the manner of a porcupine.

The animals of the small family *Chinchillidæ* were, until recently, known only by their skins, which constitute an important article of commerce. In their general organisation, they seem intermediate between the cavies and rabbits, but differ from both of them in possessing clavicles. They are all natives of South America, chiefly inhabiting the range of the Andes, and they live socially in extensive burrows.

The *Leporidæ* constitute the last family of the Rodentia, and are distinguished from the rest by the presence of two small incisors behind the rodent teeth.

Hare.

The form and habits of the typical genus, *Lepus*, are sufficiently well known in the *Hare* and *Rabbit* of this country. A large number of species exist in the different parts of the northern hemisphere, and some are inhabitants of the arctic regions. There is one species of this country, in which the brown fur, that forms its summer coat, changes to white at the approach of winter. The hare is a ruminating animal, though without the peculiarly complex stomach of the Ruminantia. The *Lagomys*, or Rat-hare, is a very interesting genus, allied to the hare, but having nearly perfect clavicles, and the fore-legs almost as long as the hind. It is chiefly remarkable for the mode in which it lays up its store of winter provisions. It lives in solitude, or in small societies, in the mountainous parts of Siberia, and hollows out its burrow amongst stones and in the clefts of rocks, and sometimes in the holes of trees. About the middle of August, these animals collect their store of winter provender, which is formed of select herbs, and these they bring near their habitation, and spread them out to dry like hay. In September, they build up the fodder they have collected into heaps or stacks, which they place under the rocks, or in other places sheltered from the rain or snow. Where many of them have laboured together, their stacks are sometimes as high as a man, and more than eight feet in diameter. These stacks, which consist of the choicest and most succulent herbs, are often pilfered by the natives of that part of Siberia for the subsistence of their cattle and horses. A subterranean gallery leads from the burrow of the lagomys, beneath the mass of hay, so that neither frost nor snow can interrupt the animal's communication with it.

The remaining orders of Mammalia may be placed on a higher level, not merely in point of size and generally of strength, but in the character of their organisation. We are first called upon to notice a cluster of animals which are usually associated in one order, on account of their being fitted to spend the whole or most of their time in the sea, but which may be more properly divided into two. The aquatic mammalia were, till no distant date, universally regarded as fish, the external figure and medium of existence being alone looked to, and no one having observed that the animals breathe the atmosphere, suckle their young, and are in many other respects different from the finny tribes.

Cetacea.

ORDER CETACEA (Whales) are in general bulky animals, resembling fish in their external figure, and entirely fitted for living in the sea. Some are herbivorous; others, carnivorous. The head is usually of enormous comparative size, and fitted closely to the body, yet not without the seven cervical vertebræ which form an almost invariable feature of mammalian animals. The anterior extremities are fashioned into paddles, for pergressive motion; while the hind extremities are united into what appears as a tail. This so-called tail, unlike that of the fish, is disposed horizontally, thus forming a powerful oar for enabling the animal to rise from the depths of the ocean to take breath on the surface, or to dive suddenly below. Under the naked apparent skin of the whales is what is now ascertained to be the true skin, composed of a thick mesh of fibrous substance, filled out with fat or blubber; forming at once an elastic padding, to enable the animal to resist the pressure of the sea at great depths, and a comfortable wrapping, to save its natural heat from escaping into the cold element amidst which it lives. As is well known, the whales are chiefly sought for and captured for the sake of the oil produced by this peculiar coating. Another feature of the whales is the situation of the nostrils terminating at the crown of the head, and forming spiracles through which they project the sea-water, mingled with their breath.

The herbivorous Cetacea are named *Manatidæ*, from the resemblance of their anterior extremities to hands. They live upon submarine plants, and the herbage which grows on the banks of rivers. They seldom exceed fifteen feet in length. The *Dugongs* of the Indian Archipelago and Red Sea are the most remarkable species. It is supposed that the many fabulous stories regarding Mermaids have taken their rise from certain species of the Manatidæ, in which the head and face, when seen alone above the water, strongly recall the human lineaments.

The *Balænidæ* attain the length of seventy feet, of which the head always forms a large part. In the mouth, instead of teeth, is an apparatus which, in the circumstances, serves the animal more effectually for the supply of its food. This is a series of horny plates, arranged round the jaws, and forming simply a *strainer*. The animal, having taken in a huge mouthful of water, containing cuttle-fishes and other small animals, expels the water through this apparatus, leaving the prey behind, which is then swallowed. This peculiar construction has a parallel in the duck tribes, whose bills are furnished with a somewhat similar apparatus. From this *baleen*, as it is called, is derived the article in common use under the name of *whalebone*. It gives a generic name to the group of animals possessing it. The *Common Whale* (*Balæna mysticetus*) is an inhabitant of the arctic seas, and its capture, as is well known, is the subject of a great trade. The sailors transfix it with a harpoon, to which a line is attached, and when it rises exhausted to the surface, they kill it, and extract

the blubber. The great danger of this business is from the tail of the whale, which is quite able to upset a boat, or even to cut it in two. The *Rorqual* is another species, in the same seas, different chiefly in being longer, with a more slender body.

Whale Harpooning.

The *Physeteridæ* (Cachelot or Spermaceti Whales) are inhabitants of the Southern Ocean. They are distinguished by the bulk of their heads, in which a surprising quantity of fat is lodged.

The *Delphinidæ* are smaller animals, generally seen in droves, and remarkable for their active and lively movements in the water. The *Dolphin*, from which the group is named, has been the subject of many fabulous stories. It was in use for food throughout the middle ages, partly in consequence of its being allowed, as a supposed fish, to be eaten during Lent. The *Porpoises* are the most familiar on our shores, to which they often come in pursuit of herrings. One remarkable species of the Delphinidæ is the *Narwhal*, or Sea-unicorn, in which one of the front teeth is developed to the surprising length of six feet, forming, of course, a most formidable weapon. The Narwhal is, however, comparatively inoffensive.

Phocidæ.

FAMILY PHOCIDÆ comprises the remainder of the aquatic mammalia. By Cuvier they were associated with the carnaria of the land, to which, it must be owned, they make a near approach. They are, in general, much smaller animals than the Cetacea, from which they differ, too, in being fitted for a partial residence on land. Their four membraned feet form powerful oars for swimming, and can also be used in clambering along the rocks. They are covered with a short close fur, sitting flat upon the skin. They pass the greater part of their time in the water, which they only quit to bask in the sunshine and to suckle their young.

Of the two genera, the *Seals* and the *Morses*, which

Greenland Seal.

this family contains, the former presents the least departure from the general type of the order. It possesses all three kinds of teeth; but the canines are not particularly large, and the molars are neither adapted for shearing nor for grinding the food, but are furnished with angular points adapted to keep hold of and crush the slippery prey. The head of the seal resembles that of a dog, presenting the same mild and expressive physiognomy. These animals seem to possess considerable intelligence; they are easily tamed, and become much attached to their feeder. They subsist on fish, which they always devour in the water, closing the nostrils by a kind of valve. Seals of various kinds are extensively scattered over the polar regions of both hemispheres, becoming scarcer in the temperate zone. They are occasionally seen on the coast of South Britain, but are more abundant on the north of Scotland. The fur-seal of the South Seas is extremely abundant in some localities; for a period of fifty years, not less than 1,200,000 skins were annually obtained from a single island.

The *Walrus* (also called Morse, Sea-cow, Sea-horse) resembles the seal in the general form of the body and limbs, but differs considerably in the head and teeth. The lower jaw has neither incisors nor canines, and is compressed laterally to pass between two enormous canines or tusks, which issue from the upper one, and are directed downwards, sometimes attaining a length of two feet. These seem to be used by the animal in hooking up the sea-weeds on which it partly feeds. The Morse is a very bulky creature, exceeding the largest bull in size, and attaining the length of twenty feet. It is an inhabitant of all parts of the arctic seas, usually assembling in large numbers; and individuals have occasionally visited the British shores.

Two orders of the remaining Mammalia are distinguished by having the extremities serviceable only for support, and terminating in *hoofs*. They are destitute of clavicles, and may be generally described as vegetable feeders. These two orders are classed together as *Ungulata*, or Hoofed Animals. The first order we shall notice is the

Ruminantia.

The ORDER RUMINANTIA is perhaps the most natural and best determined of the mammalian class, for all the species which compose it seem constructed, as it were, upon the same model, the camels alone presenting any considerable exceptions to the general characters of the group. The first of these characters is the entire absence of incisor teeth from the upper jaw; whilst the lower appears to possess eight: of these, however, the two outer ones are really canines, which have taken the form of incisors, so that the number of the true incisors is six, as in the other viviparous mammalia. The molars are almost always six in number, both above and below, and have their crowns marked with two double crescentic ridges of enamel, which aid in masticating the food. The feet are each terminated by two toes and two hoofs, which present a flat surface to each other, appearing as though a single hoof had been cleft; hence the names that have been applied to these animals of cloven-footed, &c. Behind the hoof there are always two small spurs, which are the vestiges of lateral toes.

The name of the order intimates the singular faculty possessed by these animals of masticating their food a second time, or 'chewing the cud.' This faculty depends on the structure of their stomachs, which are four in number. The food, which is cropped by the incisor teeth, is swallowed almost without mastication, and is moistened in the stomach; and after being compressed into little pellets or *cuds*, is returned to the mouth, to

be rechewed while the animal is at rest. When this operation has been performed, the food is transmitted to the true digestive stomach. This remarkable provision has a very interesting adaptation to the general structure and characters of these animals. The Ruminantia, taken as a group, are timid, and destitute of powerful means of defence against their foes. They rather seek their safety in flight when attacked. Their food, consisting chiefly of the grasses of various kinds, requires to be thoroughly masticated before it can be properly digested. When feeding, they are liable to many alarms; and if they were compelled to spend a considerable time in masticating their food before swallowing it, they would often be in danger of starvation, by being obliged to leave the pasture before their wants were supplied. But by their power of subsequent rumination, they are enabled to dispense almost entirely with the first mastication, and to feed with comparative quickness. They convey a store of food into the first stomach or paunch; and then, retiring to a secure place, they prepare it for digestion at their leisure.

The whole structure of these animals corresponds with the account just given of their habits. Their legs are long in proportion to the body, and the spinal column is very flexible; both which conditions are favourable to great activity of motion. They are endowed with a very acute sense of smell, which seems to be the guide in the selection of food. Their ears are placed far back, and are very movable; and these are well adapted to catch sounds from behind, so as to warn the animals of danger whilst feeding. The eyes are placed at the sides of the head, and the pupil is in the form of a horizontal oblong; so that the range of vision along the surface of the earth is very great, and the animals can easily look behind them when pursued. Their means of defence consist in the use of their horns to gore an enemy, and of their hind-feet to kick; but it is only when peculiarly courageous, or in defence of their young, that single animals of this order will act on the offensive, or stand on the defensive, against others of proportional size and strength.

The Ruminants are, of all animals, the most useful to man. They supply him with a large proportion of his animal food. Some serve him as beasts of burden; others furnish him with their milk, their tallow, hair, leather, horns, and other useful products.

The great resemblance which exists among the very numerous members of this order, renders the distribution of them into families, each characterised by some important peculiarity, a matter of some difficulty. These subdivisions are, probably, best formed from the character of the horns, which are possessed by the males of all the species in their natural state, excepting such as (like the camel) connect this order with other groups. The horns are essentially bony prominences from the forepart of the skull. In some Ruminants, commonly termed *cattle*—such as oxen, sheep, goats, and antelopes—these prominences are covered with an elastic sheath, formed as it were of agglutinated hair, which continues to increase by layers during life. It is to the substance of this sheath that the name of *horn* is commonly applied, whilst the bony support is termed the *core;* this grows during life, and never falls. In the *Giraffe*, again, the bony prominences are covered with a hairy skin, which is continuous with that of the head; and here, too, the bony part of the horn is permanent. But in the *Deer*, these prominences, which are covered for a while with a hairy skin (commonly termed *the velvet*), like the other parts of the head, have at their base a ring of bony tubercles, which periodically enlarge, and compress the nutritive vessels of the horns. These accordingly die, and fall from the skull; and the animal remains defenceless. Others, however, are reproduced, generally larger than before, which are destined to undergo the same fate. These horns, periodically renewed, are usually styled *antlers*.

The Ruminants with horny sheaths to the bony prominences, may be divided into three families:—*Antelopidæ*, or Antelope tribe, characterised by the lightness of their forms and the activity of their movements, and by the solidity of the bony core;—*Capridæ*, or Goat tribe: in these the bony core is partly occupied with cells, and the general form approaches that of the Ox tribe, but the horns are directed upwards and backwards;—*Bovidæ*, or Ox tribe: these have the horns directed upwards and forwards; the form is robust, and the movements heavy. The division of the Ruminants in which the horns are periodically cast off, constitutes only one family—that of *Cervidæ*, the Stag tribe. Another family, including only the Giraffes, and named *Camelopardæ*, is characterised by the shortness and permanence of the horns, which are covered with a skin. Of the Ruminants without horns, there are two distinct families—the *Moschidæ*, or Musk Deer, which are remarkable for their elegance and lightness, and differ but little from the rest of the order, save in the absence of horns; and the *Camelidæ*, or Camel tribe, which, in their dentition and in the structure of the extremities, exhibit a transition to the Pachydermata.

The family *Antelopidæ*, remarkable for the slenderness of form and swiftness of foot of the animals composing it, contains above seventy well-ascertained species, bearing a strong general resemblance to each other. Most of these are natives of Africa; a few species, however, inhabit Asia; a still smaller number exist in America; and one only, the *Chamois*, now remains in Europe. Among these numerous species, we meet with

Chamois.

forms that remind us of the other families of the Ruminantia—the Ox, Goat, Stag, &c. They generally associate in large herds, which migrate together in search of pastures. A species well known to the colonists of South Africa is the *Spring-bok;* which occasionally visits their cultivated lands, during seasons of drought, in innumerable herds, causing devastation wherever they pass. Another noted species is the *Gazelle*, celebrated for its beautiful eyes, as indicated by the poet:

> I never nursed a young gazelle,
> To glad me with its soft black eye, &c.

They are extremely vigilant and timid; and the speed of the swiftest species surpasses that of every other mammiferous animal. Those which are adapted to live on rocks and mountains exhibit the most remarkable agility, and fearlessness of those dangers which their habits would seem to involve: they walk with perfect composure along the giddy brinks of the most awful precipices, climb and descend with wonderful care and precision, and leap up or down to the smallest surface that will contain their collected feet, with perfect firmness; and yet they are so fearful of any supposed enemy, that it is difficult to get within gunshot of them. Allied to the Antelopes is a very curious genus, the *Gnu*, which at first sight seems to be a monstrous being, compounded of parts of different animals. The body and crupper,

also the tail, neck, and mane, resemble those of a horse; whilst its horns are like those of the Cape buffalo; and

Gnu.

its legs are as slender and light as those of a stag. It inhabits Southern Africa.

The family of *Capridæ* is connected with the last by many antelopes which, like the chamois, approach the goats in form. It includes only the *Goats* and *Sheep*. The original stock of the domestic breeds of the former appears to be indigenous to Persia, where it inhabits the mountains in large troops. The goats of Angora, Tibet, &c., celebrated for the fine quality of their hair, are no more than varieties of the common species. The *Ibex*, which inhabits the mountains of the Old World, and especially the Caucasian chain, is distinguished by the size and strength of its horns. It is said that this animal fearlessly precipitates itself down precipices, always falling on its horns, the elasticity of which secures it from injury. The *Sheep* appear to have extremely little real difference from the goats; a large number of races exist, the relation of which to each other is uncertain; and there is doubt as to the original stock of the whole. Of the domestication of this animal, we have an earlier record than of any other; and on its use to man, there is no need to enlarge in this place.

The species of the family *Bovidæ*, or Ox tribe, are comparatively few. They are all large animals, with a broad muzzle, heavy and massive body, and stout limbs. Of the original stock of the domestic ox, we have no certainty, since, as in the case of horses, the existing races of wild cattle may have all been descended from those which have been at some period subservient to

Bull.

man. Of all the animals which have been reduced to his service, the ox is, without exception, that to which he is most indebted, for the extent and variety of his means of usefulness. The universal utility of the animal appears to have been very soon detected; and we find, consequently, that its domestication soon followed that of the sheep, and that it is mentioned in the most ancient records as a servant of man, long before either the horse or dog is noticed. The ancient accounts of the *Urus*, or Wild Ox, declare it to have been an animal of great size and fierceness, with large spreading horns; and bones are found in the most recent deposits, both in this country and on the continent, which correspond with that description. Many races or breeds of oxen exist in different parts of the world, which were probably all descendants from one stock, and yet differ considerably from one another. Most of those inhabiting the torrid zone have a lump of fat upon the shoulders, which increases in size in proportion to the abundance of their food. This is especially remarkable in the *Indian* or *Brahmin Bull*, which, being held sacred by the Hindoos, is supplied with food in great profusion, and leads an indolent life. When left to themselves, their form changes; they become less bulky and more active, and the hump, in particular, greatly diminishes. Some of the tropical races of oxen are no larger than a hog.

Amongst the undomesticated species of this family, which have all a strong general resemblance to each other, and are the most powerful and savage animals of the whole order, may be noticed the European *Bison*, which was formerly spread over Europe, but is now restricted to Lithuania and the Caucasian region; the American bison, commonly called *Buffalo*, which inhabits

Bison.

all the temperate parts of North America; the *Indian Buffalo*, of which there are several different races (in one the horns include a space of ten feet from tip to tip), some having been domesticated; the *Cape Buffalo*, an extremely ferocious animal, with large horns, first directed downwards so as nearly to cover the forehead, inhabiting the woods of Caffraria; and the *Musk Ox*, a species inhabiting the coldest regions of North America, with short legs, and long hair reaching the ground, which diffuses more strongly than the rest the musky odour common to the whole genus, and which is particularly noticeable in the European bison.

The family *Cervidæ*, or Stag tribe, includes, like that of antelopes, a large number of species differing but little amongst each other, very widely diffused over the earth's surface, and easily separated from others by the character of the horns. With the exception of the reindeer, however, the female is destitute of horns, save in a few rare individual cases, analogous to those amongst birds in which the hen assumes the plumage of the cock-bird. This never takes place until the latter part of the animal's life. The substance of the horns, when completely developed, is that of dense bone, without pores or internal cavity; their figure varies greatly according to the species, and even in the same individual at different ages. These animals are extremely fleet, and live mostly in forests, where they feed on grass, the leaves and buds of trees, &c.

This very extensive genus may be subdivided into sections, according to the form of the antlers. In some species they are wholly or partially flattened. This is the case, for example, with the *Elk*, one of the largest

existing species, which lives in troops in the marshy northern forests of both continents. In size it approaches the horse, and sometimes exceeds it. The antlers of the male, at first dagger-shaped, and then divided into narrow slips, assume, at the age of five years, the form of a triangular blade, with tooth-like projections on the outer edge. These increase with age; so that the horns have at last fourteen branches proceeding from each expanded portion, and weigh fifty or sixty pounds. To this group also belongs the *Reindeer*, so serviceable to the Laplanders, which is the only species properly domesticated,

Reindeer.

though others are doubtless susceptible of being so. The *Fallow-deer*, now naturalised in this country, but probably introduced from the south of Europe, or even originally a native of Barbary or Western Asia, is another species of this group. The remains of a gigantic species of deer, belonging to the same section, are frequently found in peat-bogs, and other recent deposits in this country, and more especially in Ireland, whence the name *Irish Elk* has been given it. Judging from specimens of which the greater part of the bones have been discovered, it must have stood more than six feet high, and have been nine feet long; but there is no doubt, from the dimensions of many of the horns which are preserved (one pair measuring thirteen feet between the tips), that this is under the average size of the race.

The species with round antlers are more numerous; those of temperate climates change colour, more or less, with the seasons. The Common Stag, or *Red Deer*, is the best known of these, being indigenous to the forests of all Europe and of the temperate parts of Asia. The Canadian Stag, or *Wapiti*, the Elk of the Anglo-Americans, is a fourth larger. There is also another species, inhabiting Virginia and the central parts of North America, which is smaller than the European stag, and is known as the *Deer*. A large number of species are indigenous to Central and Southern Asia, of which some have been naturalised elsewhere.

Of the family *Cameloparda*, only one species was for a long time known to exist; but there are probably two, or even three kinds of giraffe, all of which are natives of Africa, mostly frequenting the borders of the deserts. Its remarkable form, depending chiefly on the great length of the neck and fore-legs, is familiar to every one. In general structure, however, it closely resembles the deer, differing from them in the permanence of the horns. It has also some points of affinity to the camels, especially in the length of its neck, the existence of callosities, or hard surfaces, on the breast and knees, and the absence of the small spurious hoofs. It is the tallest of all animals, the head being frequently raised eighteen feet from the ground. Its disposition is gentle, and it feeds on leaves; browsing upon the young branches at a height much above that which any other animal can reach, and drawing them towards its mouth by its prehensile tongue. It lives in small troops of five or six individuals, and is very timid, although capable of powerfully defending itself by kicking. Notwithstanding its length of neck, the number of vertebræ

Giraffe.

which this part contains is no greater than in other Mammalia.

The *Moschidæ*, or Musk Deer, are completely intermediate between the true Deer and the Camel tribe, which last connects the Ruminantia with the Pachydermata. They resemble the ordinary Ruminants in the lightness and elegance of their forms, and in the nimbleness of their movements; and differ chiefly in the absence of horns, and in the projection of the canine tooth on each side of the upper jaw, as in the camels. The name of this group has been derived from the common *Musk*, the males of which secrete the odoriferous substance so called in a small glandular bag. This species is nearly destitute of the tail; and the hairs, which completely cover it, are so coarse and brittle, that they might almost be called spines. It is confined to the mountainous region between Siberia, China, and Tibet, from which most of the Asiatic rivers descend. Its habits are nocturnal and solitary, and its timidity extreme. The other deer inhabit the warmer parts of Asia and the Eastern Archipelago; they have no musk-pouch. They are the smallest and most elegant of the Ruminantia, and are active and gentle in their habits.

The *Camelidæ*, or Camel tribe, approximate to the succeeding order, and especially to the whole-hoofed division constituting the Horse tribe, more closely than any other Ruminants—to such a degree, indeed, that some naturalists prefer associating them with that group. They have always canines in both jaws, and two of the incisors have also the same pointed shape. The animals of this family are much less elegant in form and graceful in action than the other Ruminants; but their organisation is, equally with theirs, perfectly adapted to the circumstances in which they exist. The family contains two groups—the *Camels* and *Llamas;* the former are restricted to the Old World, and the latter correspond to them in the New.

In the true *Camels*, the two toes are united below by a kind of horny sole, almost to their points, which terminate in small hoofs; and there is a soft cushion beneath the foot, by which it bears upon the sandy surface over which it is formed to move. Two species are known—one called the *Bactrian*, or Two-humped Camel, and the other the *Arabian*, or One-humped. Both are completely domesticated, and their utility as beasts of burden is universally known. The first species is employed chiefly in Central Asia, the latter in Arabia, North Africa, Syria, Persia, &c. The Two-humped Camel is the larger and stronger, being capable of sustaining a burden of above 1000 pounds, and is best adapted for rugged ground. The other is the most abstemious, and the best fitted for the sandy desert.

The *Dromedary* is merely a lighter variety of it, possessed of greater fleetness and power of endurance.

Bactrian Camel.

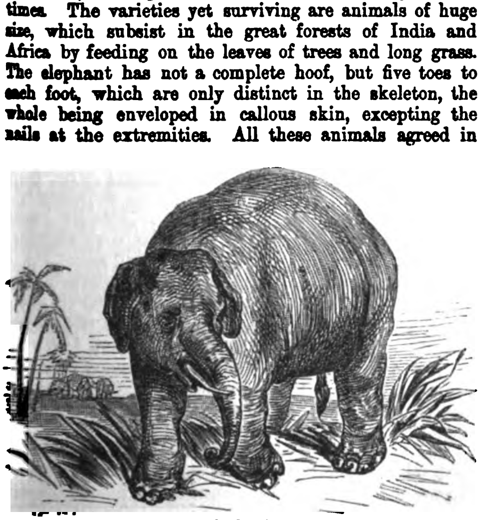
The flesh and milk of the camel serve as food, and the hair for the manufacture of cloth. Their humps, principally composed of fat, are provisions of superabundant nutriment, which are gradually absorbed and disappear on the occasion of a scarcity of other food, as is observed at the end of a long journey. By resting on their callosities, they are enabled to repose on a scorching surface, and their stomachs are adapted to contain a supply of water sufficient for several days.

The *Llamas* of South America are much smaller than the camels; they have the two toes quite separate, and are without humps. They were the only beasts of burden possessed by the Peruvians at the time of the conquest. They can only make short journeys, and the largest of the four species known cannot sustain more than 150 pounds. Remains of a fossil species have been found, which must have equalled the camel in stature.

Pachydermata.

The second of the Ungulated orders is the PACHYDERMATA, so called from the thick skin with which most of them are invested. The animals of this order do not ruminate. They may be divided into three sections or groups.

Of the first group, *Proboscidea*, the *Elephant* is the only living genus; other species, as the *Mammoth* and *Mastodon*, having become extinct in not very remote times. The varieties yet surviving are animals of huge size, which subsist in the great forests of India and Africa by feeding on the leaves of trees and long grass. The elephant has not a complete hoof, but five toes to each foot, which are only distinct in the skeleton, the whole being enveloped in callous skin, excepting the nails at the extremities. All these animals agreed in



Elephant.

possessing a pair of enormous tusks or front teeth, and a very elongated nose or proboscis; and it is probable that this last organ was formed, as in the elephant, to answer the purposes of a hand—laying hold of large objects by coiling itself round them, and of small by means of the finger-like organ at its extremity. The magnitude of the sockets necessary to hold the tusks, renders the upper jaw so high, that the nostrils, which are prolonged through the trunk, are placed in the skeleton near the top of the face. The trunk is admirably adapted to serve both as a means of laying hold of food and imbibing water: when the capacious nostrils are charged, the animal bends the trunk towards the mouth and discharges the liquid into its throat. By this organ, the shortness of the neck—rendered necessary by the weight of the head—is fully compensated. The cavity for the brain by no means corresponds with the external form of the skull; for in order, as it would seem, to give a larger surface for the attachment of the muscles of the trunk, the outer layer of bone is widely separated from the inner, and between the two are a number of large bony cells.

In none of the Proboscidea has the lower jaw of the adult any front teeth. The arrangement of the grinders differs in the various species; but in all they are composed of alternating plates of hard *enamel* and softer *bony* matter, cemented together by a third substance, which is termed the *cortical*. These grinders are in constant progress of renewal; but they succeed each other, not by rising from below upwards, as in man, but by being pushed forwards from behind, in proportion as the tooth before each is worn away. The tusks are only changed once; but, like the cutting-teeth of the rodents, they are constantly being renewed at the roots. Two species of elephants exist at the present day, both of which inhabit tropical climates—one in Asia, the other in Africa. Remains of the mammoth are found chiefly in the north of America and in Siberia; and from a nearly perfect specimen, which was discovered frozen in the ice near the mouth of the river Lena, it appears that this species was adapted to live in cold climates—the skin being densely covered with hair of two kinds. The tusks of the elephant serve not only as weapons of offence and defence, but to root up small trees and tear down cross-branches, either to obtain their leaves or to make a passage for the bulky body of the animal through the tangled forest.

Of the second group, sometimes called the *True Pachydermata*, the first family is that of *Suidæ*, the Pig kind. It is characterised by the peculiar thickness of the skin, and by the presence of four toes on each foot. They have three sorts of teeth in each jaw; the canines are usually long, and project forward as tusks; the anterior molars are more or less narrow and conical, whilst the posterior are tuberculated. The food is principally vegetable, but admits of considerable variation. The domesticated pig is well known to be quite an omnivorous animal. In the true *Pigs*, the foot has two toes furnished with large hoofs, and two much shorter ones that scarcely touch the ground. The *Wild-boar*, which abounds in some parts of the continent of Europe, is well known to be a very ferocious animal; and the domesticated race which is derived from it often exhibits indications of the same character. One of the most curious animals of this tribe is the *Babyroussa*, a native of the Indian Archipelago; the upper canines of which are very long, and grow spirally upwards and backwards. These serve as defensive weapons of a very powerful description, inflicting severe lacerations by an upward stroke of the head. The *Peccaries* of South America want the external toe, and the central ones are partly joined together, as in the Ruminants; to which the complex structure of their stomachs also exhibits their affinity.

With the family of Suidæ is probably to be placed the *Hippopotamus*, or River-horse, which seems in many respects intermediate between the pig and the elephant; whilst by its aquatic habits, and the conformation by

which it is adapted to these, it approximates to the Dugongs. Only one species is known, which is now

Hippopotamus.

confined to the rivers of Central and South Africa. But for its short, thick, and very blunt muzzle, it might be compared to a gigantic pig. The canine teeth are long; the upper ones straight, and the lower curved backwards, so that they rub against each other. Although courageous when attacked, these unwieldy inhabitants of the waters are in their nature shy, and feed entirely on roots and other vegetables, seeming to prefer those which are partially decomposed by the action of water.

The second family of true Pachydermata—to which the name of *Tapiridæ*, or the Tapir tribe, may be given—resembles the first in the thickness of its skin, but differs in the arrangement of the toes, of which there are only three on each hind-foot, and sometimes also in front, without any central cleft. There is considerable variation in regard to the teeth; but the whole family is exclusively herbivorous. No members of it exist in Europe at the present time; but fossil remains of very large species are abundant in some localities. The *Tapir* of America is about the size of a small ass, with a brown and almost naked skin, a short tail, and fleshy neck that forms a crest at the nape. It is common in humid places and along the rivers, and its flesh is eaten. The nose assumes the form of a short fleshy trunk—the rudiment, as it were, of that of the elephant. Other species have been recently discovered of a larger size; one of which has the bones of the nose still more elongated, approaching a very remarkable fossil genus—the *Palæotherium*. This seems to have been an animal nearly allied to the Tapirs. Remains of several species, varying in size from a rhinoceros to a small sheep, have been found in the gypsum quarries of Paris, the fresh-water deposits of the Isle of Wight, and other places.

To this family belongs the *Rhinoceros*, which is remarkable for its large size, and for the kind of horn, composed of a solid fibrous substance, resembling agglutinated hairs, which is supported on an arch formed by the nasal bones. Several species exist in different parts of the tropical portion of the Old World. They are naturally stupid and ferocious, frequenting marshy places, and subsisting on herbage and the branches of trees. In some species a second horn exists behind the first. The upper lip is generally elongated, and has some power of prehension. The bones of the rhinoceros have been disinterred in many parts of Europe. There is a curious little animal, the *Hyrax*, which is about the size of a rabbit, and was formerly placed among the Rodentia; it is, however, little else than a rhinoceros in miniature, without the horn. It is not uncommon in rocky places in Africa and Syria, and one species ascends trees. It is probably the animal spoken of in Proverbs xxx. 26, as the *cony*.

The third group of Pachydermata, the *Solidungulata*, contains only one family—that of the *Equidæ*, or Horse tribe. Though there is only one apparent toe and single hoof to each foot, there are appendages beneath the skin which represent two lateral toes. The well-known animals of this tribe, the Horse, Ass, Zebra, Quagga,

Zebra.

Onagga, and Dzegguetai, are commonly regarded as belonging to but one genus; but the first of these is probably to be separated from the rest, from the circumstance of its tail being wholly clothed with long hair, whilst that of the rest has long hair only towards the tip. The Ass and Horse are noted for their usefulness to man as beasts of burden, docility and strength being in them combined in a remarkable manner, but particularly in the horse. In a wild state, the horse lives in great herds, browsing on grassy plains, and occasionally moving over them with marvellous swiftness.

All the animals just named agree in their dentition. There are six incisors to each jaw, which, during youth, have their crowns furrowed by a groove, and six molars on each side, above and below, with square crowns, marked, by plates of enamel which penetrate them, with four crescents. The males have, in addition, two small canines in their upper jaw, and sometimes in both; these are always wanting in the females. Between the canines and the first molar there is a wide space, which corresponds with the angle of the lips, where the *bit* is placed, by which alone man has been enabled to subdue these powerful quadrupeds. None of the species of this family are indigenous to America.

Carnivora.

The animals composing the ORDER CARNIVORA are separated from the other Mammalia possessing distinct fingers, by the presence of three kinds of teeth, and from these orders they are distinguished by characters which point them out as especially formed for the pursuit and destruction of large animals. They possess in the upper and lower jaw six incisor teeth; a large, strong, and pointed canine tooth on each side; and molar teeth which are evidently formed for cutting and tearing, rather than for bruising or grinding. The form of these teeth varies, however, in the different genera, in accordance with their several habits. These molars consist of three kinds: the anterior, immediately following the canines, which are always more or less pointed, and are termed *false molars;* the next class, formed especially for cutting the flesh upon which the animals feed, are termed *carnivorous teeth;* and the posterior are tuberculated, with flattened summits.

The proportion which these different classes bear to each other in number and development, accords with the degree of the carnivorous propensity of the animal, and furnishes important characters in the subdivision of the order. The more the surface of the molar teeth is raised into points and edges, and the more the action of the jaws is restricted to the scissor-like movement by

which these edges are made to meet and pass each other, the more purely carnivorous is the regimen of the animal: this is well seen in the Cat tribe. On the other hand, the more the molar surfaces are flattened, and the greater the lateral grinding motion of which the jaws are susceptible, the greater is the probable admixture of vegetable food: this is seen in the Bears. The general structure of the body, and especially that of the extremities, is modified in a corresponding manner, in accordance with the habits and propensities of the animal. In all, the toes are furnished with claws, which are peculiarly sharp in the Cats, and are in them kept ready for use within a sheath, from which they can be projected at the will of the animal. The stomach of the Carnivora is very simple in its form, and the intestines are short, in accordance with the easily digested character of their food.

The whole bony and muscular system exhibits a similar modification. Thus, whilst the powerful yet active and flexible movements of the purely carnivorous animals are adapted only to the pursuit and destruction of living prey, the more sluggish habits of most of the Bear tribe, their peculiar mode of progression, and the modified structure of the skull, the teeth, and the limbs, are all equally applicable to the mixed nature of their food. The difference in the conformation of the extremities, and in the mode of using them, is very striking in these two antagonised groups. In the former, the ends of the toes only touch the ground, the heel being considerably raised into the air; in this way, the limbs can be used to much greater advantage in running and springing: the animals possessing this conformation are termed *Digitigrade Carnivora*. In the latter, the whole foot rests on the ground—a structure more favourable to the maintenance of a firm position, but preventing great activity of progression: these are called *Plantigrade Carnivora*. In the seals, which may be considered as Carnivora fitted for a sea-life, there is a third very remarkable variety of conformation in the extremities. Here, as we have seen, the anterior, as well as the posterior feet, are formed for swimming, being spread into fin-like paddles; and the whole arrangement of their organs is admirably adapted to the pursuit and capture of their scaly prey.

The *Carnivora* may be subdivided into four families, each containing a well-known form. 1. *Felidæ*, or Cat tribe.—In these the destructive power is most highly developed. They are characterised by their short powerful jaws, their retractile claws, and the peculiar adaptation of their teeth for cutting. They have but one small flattened molar tooth above, and no corresponding one below. 2. *Canidæ*, or Dog tribe.—These, like the cats, are digitigrade; but their claws are not retractile; and they have two flat tuberculated molars behind the great flesh-cutter. 3. *Mustelidæ*, or Weasel tribe.—These are mostly semi-plantigrade, a portion of the sole touching the ground. They are distinguished by their long narrow bodies, and by the presence of only one tuberculated molar. 4. *Ursidæ*, or Bear tribe.—These are the only true Plantigrade Carnivora. Most of them possess several tuberculous teeth. In some systems, the *Phocidæ*, or Seals, are presented as a fifth family of Carnivora.

The *Cat* tribe includes a large number of animals very closely resembling each other in structure and aspect—so closely indeed, that many of the species can only be distinguished by their size, and by the markings of their skin. They all agree, too, in the mode of catching their prey, which is to steal upon it unawares, and seize it with a sudden spring, in which they expend their energy, often slinking off when once baffled. It is very difficult to subdivide the family, on account of the strong general resemblance of its members. Most of them are sufficiently well known to render any peculiar description necessary. It may, however, be remarked, that some species are found in almost all tropical and temperate countries, and that those of different parts of the globe *represent* each other in a remarkable manner. Thus, the *Lion* and *Tiger* are inhabitants of Africa and

Tiger.

tropical Asia; in America, they are replaced by the *Puma* and *Jaguar*, which are confined to that continent. In the same manner, we find the *Panther* and *Leopard* spread over tropical Asia and Africa; the *Ounce*, inhabiting the Asiatic mountains; the *Caracal*, in Turkey and Persia; and the *Lynx*, in Northern Europe. These are represented by the *Ocelot* in South America, the *Lynx* of Canada (differing from the European), and other less-known species. The Felidæ, like the noble falcons, will only eat the flesh of animals they have themselves killed, except when in a state of domestication or confinement, or when compelled by hunger.

The family of *Canidæ* includes a much larger number of different forms, some of which approximate to the Cat tribe, and others to the weasels and bears. This tendency to variation from a typical form is most remarkably shewn in the races of the *Common Dog*, which are believed to have all had the same origin, although the commencement of most of them is entirely unknown. The animals of this family agree in their greater or less adaptation to a mixed diet. Although animal flesh naturally constitutes the principal food of all, they do not attack living animals with a degree of boldness proportional to their strength; and many of them feed upon carrion, sometimes even when it is much putrefied. The *Wolves*, *Foxes*, and *Jackals*, are the animals which most nearly approach the dog; and the first of these is regarded by many naturalists as being really identical. A very curious connecting-link between this division of the family and the hyænas, is the Wild Dog of the Cape (*Lycaon picta*). This resembles the dog rather than the hyæna in its teeth; but in its tall gaunt form, and general aspect, it is more analogous to the latter, which it is also believed to resemble in internal formation. It lives in numerous packs, which often approach Cape Town and devastate the environs.

The *Hyænas* constitute a group remarkably distinct from the true Canidæ, and yet bearing enough of their characters to require to be associated with them. They are more purely carnivorous than the dog tribe, and in the deficiency of tuberculated molars, approach the cats. But they differ from these, not only in general aspect, which is much more nearly allied to that of the dog, but also in the absence of the retractile power of the claws, and in their propensity to feed on carrion. The teeth are peculiarly adapted for crushing bones, and their jaws are shorter than those of the dog, but longer than those of the Felidæ. In many other points of structure, the Hyænas are intermediate between the two groups. They are peculiarly ferocious animals, combining the persevering *doggedness* of the one tribe with the furious blood-thirstiness of the other. Their habits are nocturnal—more so than those of most other

Carnivora. Hyænas are now chiefly confined to Africa and the south of Asia; but there is no doubt, from the

Hyæna.

abundant remains of them which are preserved to us, they must have formerly lived in large numbers in this country and in other parts of Europe.

Another curious South African animal conducts us from the hyænas towards the *Civet* tribe, which consists of small animals, some resembling the cat in form, but having two or more tuberculous grinders, and in many instances a plantigrade walk. In the true *Civets*, there is a pouch situated near the tail, containing a secretion of a musky odour, which is valued as a perfume. They are beautiful spotted animals, natives of Africa and India; they are of an indolent disposition, easily tamed, and feed partly on fruits. Allied to these is the celebrated *Ichneumon* of Egypt, which is an animal larger than our cat, and as slender as a marten, sharing in the highly carnivorous propensities of the next family. It chiefly hunts for the eggs of crocodiles, by destroying which it prevents the excessive multiplication of those reptiles. It is easily domesticated, and exhibits much intelligence; and it is brought up in houses, to keep them free from mice and other small animals. The ancient allegation of its entering the throat of the crocodile to destroy it, is quite fabulous. The common Indian species is celebrated for its combats with the most venomous serpents.

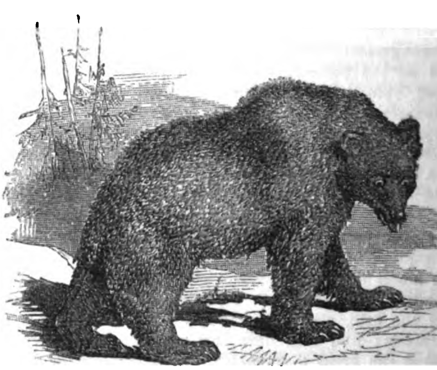
The *Mustelidæ* are the most *blood-thirsty* of all the Carnivora; but they are not so well adapted for devouring flesh as the Felidæ. These animals, on account of their length of body and the shortness of the limbs, which permit them to pass through very small openings, may be described as *Vermiform*. All the members of this family are semi-plantigrade; and they thus conduct us to the truly Plantigrade Carnivora. The *Weasel* of this country is a very characteristic example of the family; it is one of the most sanguinary of all, but confines itself chiefly to small animals, destroying large numbers of mice, rats, moles, &c. The *Ferret* and *Marten*, which are allied species, are bolder, having been known to attack man; and the *Polecat* is a great enemy to the farmyard, game-preserve, and warren. All these animals have a strong and disagreeably odorous exudation from a pouch under the tail; but it is most disgusting in the last, from which cause it is often called the *Foumart* (a corruption of *foul marten*). The *Skunks* are an American tribe, intermediate between the weasels and badgers, and are remarkable for the intensity of their nauseous suffocating stench.

The *Otters* constitute an aquatic form of this family, having the same general aspect and dentition as the weasels, but being readily distinguished from all other genera of the family by their webbed toes and horizontally flattened tail. They subsist on fish. Several species exist, which are diffused pretty universally over the globe, with the exception of Australia, where they are replaced by the extraordinary *Ornithorhynchus* (see page 174). The Indian species is employed for fishing, as the dog for hunting. A large species frequents the waters of the North Pacific Ocean, along the shores of Kamtchatka and Siberia, where it is hunted for its blackish velvet-looking fur. This species is said to feed partly on sea-weed. The *British Otter* also occasionally

Otter.

visits the sea, swimming to some distance from the mouths of the rivers which it has descended. It is said to burrow in their banks; but this is not correct, as it lives only in natural excavations. When the supply of fish is scanty, it has been known to resort far inland, and to attack lambs, sucking-pigs, and poultry.

The true Plantigrade Carnivora, constituting the family of *Ursidæ*, participate in the comparative slow motion and nocturnal life of the Insectivora; and like them, too, the species which inhabit cold countries pass the winter in a dormant state. In the *Bears*, the



Brown Bear.

cartilage of the nose is elongated and movable, somewhat resembling that of the shrews. These animals possess a great facility, from the structure of the sole, for rearing themselves up on their hind-feet; and this may be especially noticed in such as are, like the bears, fruit-eaters, becoming carnivorous only from necessity; they are thus enabled to climb trees in search of food. The bear also digs the ground in search of earthworms, on which it feeds, besides slugs, snails, small mammalia, and birds, eggs, and vegetables.

The *Badgers* (*Taxels* or Badgers of America) and the *Wolverines* form a tribe connecting the Bears with the Mustelidæ. The *Badger*, for example, is only semi-plantigrade, and has a dentition very like that of the weasels and otters, but adapted for a less carnivorous regimen. But it has the tardy gait and nocturnal habits of the other plantigrades; it does not, however, become torpid in winter. All these animals, like the weasel tribe, have the power of emitting a fetid odour

at will. The European and American badgers burrow with great facility, by means of the long claws of their fore-feet. They go forth in search of food only by night; and devour small animals which fall in their way, and such vegetable substances as roots, earth-nuts, and beechmast, almost indifferently. They are endowed with astonishing strength of jaws, and great muscular force, so as to confer upon them considerable powers of resistance. Of the Wolverines, the most celebrated species is the *Glutton* of the north, which is about the size of a badger: it is reputed to be very sanguinary and ferocious, subduing the largest animals by leaping on them from a tree. Some species of this tribe approach very closely to the Mustelidæ.

Cheiroptera.

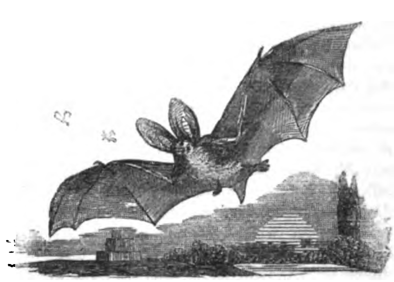
The ORDER CHEIROPTERA (*Bats*) have been placed thus high in the Animal Kingdom, in consideration of several peculiarities shewing an affinity between them and the Monkeys. They are generally small animals, of insectivorous habits, and their distinguishing peculiarity is a membrane extending over the very elongated fingers of the fore-arm, enabling them to rise and pursue their way in the air, in quest of their insect prey. The four fingers, forming the framework of the wing, correspond with those of the human hand, though much prolonged; and there is also a small thumb, terminating in a hook-like nail, which serves the animal for climbing on precipices, and in making its way along the ground. The toes of the hind-feet are short, and furnished with claws, by which the bats suspend themselves from the trees or walls on which they rest, hanging with the head downwards. From some peculiar sensitiveness of wing, the bat can make its way, while deprived of eyesight, and even of hearing, among a confused variety of objects, without ever coming in contact with any. In many of the insectivorous bats, the organ of smell is furnished with curious leaf-like appendages, formed of the integument, doubled, folded, and cut into curious and most grotesque forms. The group in which these are most remarkable, is one which avoids the light of day more than others. The arrangement may be considered as an unusual development of the sense, specially useful in those circumstances.

The families composing the *Cheiroptera* are arranged in two divisions—one of them including the strictly Insectivorous Bats, the other comprising those which are Omnivorous, or feed chiefly on fruits. In the former, the molar teeth have tubercles, like those of the Insectivora, and the intestine is short; in the latter, the molar teeth have flattened crowns, and the stomach is complex. The Insectivorous group comprises four families:—1. *Rhinolophinæ;* in these, the nose-leaf is of complicated structure, and is membranaceous; the index or fore finger has but one joint; the wings are large and broad. 2. *Phyllostominæ*, which have the nasal appendage simple and fleshy, and an index-finger of two joints. 3. *Vespertilionidæ*, which are destitute of nasal appendages, and have a single joint in the forefinger. 4. *Noctilionidæ*, which are also destitute of nasal appendages, but have two joints in the index-finger.

To the first of these families, the *Rhinolophinæ*, belong the greater and lesser *Horse-shoe Bats*, which are found in the darkest and most secluded retreats of our own country; their name is derived from the peculiar form of the anterior nasal appendage. The family contains many other genera and species, most of which are inhabitants of the Old World. One of the most curious is the *Nycteris*, which has the power of distending the skin, which is very loosely fitted to the body, with air, blown into it through openings at the bottom of the cheek-pouches, which these animals possess. These openings are guarded by a circular muscle, which prevents the return of the air except at the will of the animal; and large valves for the same purpose exist in the neck and back. By this curious mechanism, the nycteris has the power of so completely distending the skin, as to give the idea of 'a little balloon furnished with wings, a head, and feet.' In this manner, the specific gravity of the body is diminished; and some other purpose may be answered by the contrivance, as in the case of the analogous air-cells of birds.

To the second family, the *Phyllostominæ*, belongs the celebrated *Vampire*, of the blood-thirsty propensities of which such marvellous stories have been told. The wound inflicted by its teeth is very small; but its tongue is endowed with a peculiar power of suction, by which a considerable amount of blood may perhaps be drawn. There are no well-authenticated accounts of the death of any animal having been occasioned by this creature; and the story of its fanning its victim with its wings to keep him cool, and render his sleep more profound, is probably a fiction of the imagination. Some of these bats have the tail very short, and in others it is altogether absent. They appear to feed in part upon succulent fruits; but there is one genus, the extreme shortness of whose intestine indicates that it must derive its food from animal matter almost exclusively. One of these has been taken in the act of sucking blood from the neck of a horse. The vampires are confined to South America; but other members of this family inhabit the Eastern Hemisphere. Many of them attain considerable dimensions; the body being equal in size to that of the magpie, and the wings, when expanded, measuring between two and three feet across.

The third family, *Vespertilionidæ*, is by far the most numerous, and includes most of the bats of temperate climates. At least thirteen species exist in this country, the largest of which is the *Mouse-coloured Bat*, the expansion of whose wings measures fifteen inches; but this is of rare occurrence. A more common one is the *Noctule*, or Great Bat, which is but little smaller; this is often met with in considerable numbers, seeking its retreat sometimes in the hollows of trees; at others, under the roofs and eaves of houses. Probably the most abundant is the *Long-eared Bat*, which is easily



Long-eared Bat.

distinguished by the character implied in its name. Its ears are folded downwards during hybernation or profound sleep. It is easily tamed when in confinement, and may be brought to considerable familiarity, so as to eat from the hand. It has an acute and shrill, but not loud cry.

The bats of the fourth family, *Noctilionidæ*, are almost exclusively confined to tropical countries. The number of species belonging to this group is very large, but few of them present any important peculiarities. One of the most interesting is the *Cheiromeles*, an inhabitant of Java and Siam, which has a distinct opposable thumb on the hind-feet, by which it can grasp small objects. It is, therefore, an evident connecting-link between the orders Cheiroptera and Quadrumana.

The Frugivorous or Omnivorous group contains but one family—the *Pteropinæ*. This is widely diffused throughout warm climates, and contains some of the largest species of the order. It is not improbable that

the fabulous harpy may have had its origin in some of these. None of them have the tail much developed, and in many it is entirely absent. The *Pteropus Javinicus* is a very characteristic example of this family. It is probably the largest of the bats—its expanded wings measuring five feet across. It is extremely abundant in the lower parts of Java, and uniformly lives in societies. They suspend themselves from trees during the day; and from their motionless aspect and contracted bodies, they might be mistaken for parts of the tree, or for fruit suspended from the branches. When night comes, they begin to move, and go in search of food to the forests, villages, and plantations; in all of these they do great mischief, attacking indiscriminately almost any kind of fruit, of which they devour a large quantity. In their turn, they are eaten by the human inhabitants of some of the countries where they abound, who consider them as delicacies. The flesh of the *Common Roussette* of the Mauritius has been compared to that of the hare and partridge.

The Cheiroptera inhabiting temperate climates all remain in a torpid state during the winter. Some of them make their appearance, however, in mild days; but as casual revivals during the season of repose are injurious to them, they usually betake themselves to places of which the temperature is not readily affected by external vicissitudes. The office of this group in the economy of nature is evidently to assist birds in restraining the too rapid multiplication of insects, and to keep down the luxuriance of tropical vegetation.

Quadrumana, or Monkeys.

The QUADRUMANA have an interest for us beyond most orders of Mammalia, on account of their being the animals nearest to man in external form and in intelligence. They are omnivorous animals, dwelling chiefly in the forests of warm countries, and spending much of their time on the branches of trees, among which they are well fitted to move by reason of the grasping power of their extremities. These are considered by naturalists as four hands—hence the name of the order—each hand having one finger opposed to the rest, like the thumb on the human hand. The two hinder hands, though resembling human feet, are not intended by nature to serve as a support to the entire weight of the animal. It only puts the outside to the ground, and seems awkward and insecure unless it has the fore extremities also employed in its support or in progression. The lowest of the monkey tribe have hands little advanced beyond the feet of the Carnivora, and even among the highest the organ is inferior to what it is in man. A corresponding series of gradations may be traced in the aspect of the face; for whilst, at one end of the series, the muzzle (at least in the young animal) is not much more prominent than it is in some races of man, at the other, it nearly resembles that of other Mammalia. Nevertheless, throughout the order, a certain degree of resemblance to man may be perceived in the gestures, as well as in the general aspect of these animals. All of them, like man and the Carnivora, possess three sorts of teeth; the canines, in the full-grown animal, are much more developed than in man; and there are intervals between them and the other teeth which are not present in his jaws, but exist in all other Mammalia.

The Quadrumana may be divided into three families —the *Simiadæ*, or *Monkeys of the Old World;* the *Cebidæ*, or *American Monkeys;* and the *Lemuridæ*, or *Lemur* tribe, which supply the place of monkeys in Madagascar and some parts of Africa and India. This restriction of distinct types of structure to different portions of the surface of the globe, is not a little remarkable; and it may be traced even in the subordinate divisions.

The *Simiadæ* must be regarded as the types of the Quadrumanous order; and amongst these the *Apes* manifest, in the most striking manner, the peculiar characters of the group. These are distinguished from the other subdivisions, in part by the absence of a tail, but also by the want of the cheek-pouches and of the callosities, or hard spots on their haunches, destitute of hair, which the monkeys and baboons possess; and further, by the predominance in length of the fore-feet or arms over the hinder ones. The most remarkable species of this group are the *Chimpanzee* and *Orang-outang:* the former, a native of equinoctial Africa; and the latter,

Chimpanzee.

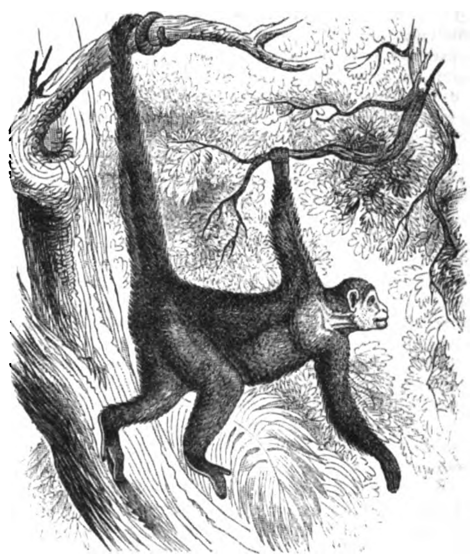
of the peninsulas and islands of Eastern Asia. Both these animals attain considerable size when full grown: the former rising to five feet, and the latter to seven; but no living specimens of those sizes have ever been seen in this country. In both, there is a remarkable difference between the young and the adult form of the skull—the young bearing the greatest resemblance to that of man, whilst in the adult the muzzle is so much prolonged, and the canine teeth are so much developed, as to give the face much more the aspect of that of the baboon. This difference, together with a change in the colour of the hair, has caused specimens of the Orang at different ages to be accounted distinct species. The character of the animal also changes, being mild and gentle when young, but having a good deal of baboon-like ferocity when come to its full development. In the *Gibbons*, or *Long-armed Apes*, the length of the anterior members is so great, that they touch the ground when the animal is in a semi-erect attitude; these present an approach to the monkeys, in the possession of callosities on the haunches by some of the species.

The *Monkeys* of the Old World are distinguished (in addition to the characters which separate them from the Cebidæ) by the possession of cheek-pouches, callosities, and a tail, which distinguish them from the apes; the tail is longer than in the baboons, the muzzle less protuberant, and the aspect less ferocious. The group contains, however, some species which present an approach to the apes, and others which form a transition to the baboons. The *True Monkeys* are also remarkable for the shortness of the arms in proportion to the legs, which causes some species to walk on all-fours with difficulty, climbing being their usual mode of locomotion; but by common observers they are still more noticed for the beauty of their colouring, their activity of movement, and gentleness of demeanour. Their character is much changed, however, by confinement. They are found in almost all the tropical countries of the Old World, and particular genera have a peculiar local distribution. Many of them live in societies, chiefly inhabiting the woods, but committing great devastations

on any cultivated ground in the neighbourhood. In several species, the aspect of the head is extremely grotesque, as are also the attitudes of the animal. Their food seems to be rather vegetable than animal; and in one genus this is distinctly indicated by the structure of the teeth and of the stomach. Another genus, restricted to Africa, is destitute of thumbs on the anterior extremities, and the deficiency is partly supplied by the great development of the tail, which is not, however, prehensile, as in the American monkeys.

The *Baboons* have usually a short tail, or none at all; but there is much variation in this respect. They are rather distinguished from the apes and monkeys by the protuberance of the muzzle, and the ferocity of aspect which is partly dependent upon this; the canine teeth are generally large and strong. The Baboons have also a large bag connected with the organ of voice, by the resonance of which the power of their loud and discordant cries is greatly increased. The animal commonly termed the *Barbary Ape* is in reality a baboon; but in the almost total deficiency of tail, it bears a superficial resemblance to the former group. A race of these animals inhabits the Rock of Gibraltar, where they manage to obtain a scanty subsistence. This is the only instance of the existence of Quadrumana in a wild state within the boundaries of Europe. The *Mandril* is the largest of the Baboons, and of the Quadrumana in general, with the exception of the chimpanzee and orang. It is a ferocious-looking animal, and is distinguished from other baboons by the bright red colour of its cheeks; it is dangerous from its size, strength, and uncertain temper, so as even to become a terror to the negroes of Guinea, of the woods of which part of Africa it is an inhabitant. The group of Baboons is almost confined to Africa and Western Asia. Dr A. Smith, a traveller in Southern Africa, states that they chiefly inhabit barren stony places, where they subsist, for the most part, upon scorpions, to procure which they employ their hands to lift up the numerous loose stones, under which one or more of these creatures commonly lie concealed: their stings they extract with dexterity. Baboons are by no means devoid of intelligence; but they do not seem capable of being steadily attached by kindness, and generally exhibit an alternation of moody sullenness and violent outbreaks of passion. Their resentment of injuries is often manifested for a long time afterwards.

The Monkeys of the New World, composing the family *Cebidæ*, differ from those of the Old, not only in the greater number of their grinders and a wider disposition of the nostrils, but in the entire absence of the cheek-pouches and callosities, and also in the conspicuous character of the tail, which is capable of being twisted round branches so firmly as entirely to support the animal. In general, the thumbs of the anterior members are not opposable; and they are sometimes scarcely developed at all. The Cebidæ are usually of smaller size than the Simiadæ, none of them attaining nearly the dimensions of the chimpanzee, orang, or mandril; they are also less malicious, more easily tamed, and susceptible of a more constant attachment; but they seem to possess less intelligence. They are found in very large numbers in the woods of South America, where they chiefly subsist on vegetable food, to which their teeth shew a peculiar adaptation. The largest of them are the *Myceti*, or *Howling Monkeys*, which derive their tremendous powers of voice from a sort of hollow drum connected with the larynx (somewhat resembling that of the baboons), which is peculiar to them amongst the Cebidæ. They are shaggy animals, about the size of a fox. The *Ateles*, or *Spider Monkeys*, are remarkable for the length and prehensile power of their tails, and for the absence (in some species entire, in others nearly complete) of the thumb; whence they are called four-fingered monkeys. A remarkable link, by which this group is connected with the Simiadæ, is afforded by the genus *Oustitis*, which includes the animals known as marmosets and tamarins. Like the American monkeys



Spider Monkey.

in general, they have the nostrils lateral, and the haunches covered with hair, and are destitute of cheek-pouches; but they have only ten grinders in each jaw, like those of the old continent. All their nails, except those of the hinder thumbs, are compressed and pointed, so as to assume the appearance of claws; and even the thumbs, though furnished with flat nails, are yet so slightly separated from the other toes, that the animals can scarcely be called 'four-handed.' The lower jaw possesses large cutting teeth, resembling those of the Rodentia—an order to which this group presents several points of resemblance. They are all diminutive animals, of pleasing forms, and very active movements; some of them are rather irritable in temper, and present an appearance which is really formidable, notwithstanding their size. There is another genus, *Pithecia*, which may be regarded as representing the baboons of the Old World among the Cebidæ; the tail being short, the head large, and the canine teeth much developed. Many of the species are strong, stout, and fierce; having a hoarse and hollow voice, and a malicious aspect. Some of them are nocturnal in their habits, and feed upon small Mammalia and birds, which they steal with great caution and noiselessness; such are distinguished by their large and prominent eyes.

The third family of Quadrumana, that of *Lemuridæ*, has in many respects the general aspect of the American monkeys; but the muzzle is much prolonged, resembling that of insectivorous or carnivorous animals; the teeth, also, are modified for animal food, presenting sharp tubercles, locking into each other; and the grinding motion of the lower jaw is reduced, so that its action possesses more of the scissor-like character of that of the animal-feeders. The four thumbs of these animals are well developed and opposable; the claw-like aspect of the nail of the first hind-finger is one of the most easily recognised characters of the family. The canines in the lower jaw have the character of additional incisors; and the first molars resemble the ordinary canines. The total number of teeth in each jaw is eighteen, as in the American monkeys. The *True Lemurs* are distinguished by their very large and handsome tails, which are elevated when the animals are in motion, and not trailed after them; they average the size of a large cat, but have

longer limbs. They are nocturnal or twilight animals, passing the day in sleep, rolled up in the form of a ball; at night they rouse themselves, and spring with the greatest activity in search of their food, which principally consists of fruits. They are entirely confined to Madagascar, where at least thirteen species are known to exist, differing from each other but little except in colour. On the other hand, the *Galagos*, which are found in the neighbourhood of the river Senegal, are pre-eminently insectivorous. With this group may be associated a very remarkable animal, which bears a strong resemblance to the sloth—the *Stenops Tardigradus*, or *Slow-paced Lori*, an inhabitant of India and the Eastern Archipelago. It has the teeth of the Lemuridæ, the short muzzle of a mastiff, a slender body, no tail, and large approximating eyes, as in the Lemurs. It subsists on insects, occasionally on small birds and quadrupeds. During the day, it sleeps, clinging to a branch, with the body drawn together; at night it prowls among the forest boughs in quest of food; its sight is then excessively acute, and it steals noiselessly on its victim. Its grasp is remarkably tenacious; and it has been found that the trunks of the arteries of the limbs subdivide, as in the true sloths, into a net-work of branches, the object of which seems to be to retard the blood in its passage amongst the muscles.

In this group may be placed two remarkable animals, which, from their strong resemblance to other orders, were associated with them by Cuvier and other naturalists. The first of these is the *Galæopithecus*, or *Flying Lemur*, which, from its strong resemblance to the bats, has been arranged with the Cheiroptera. It is, however, a *lemur* in all its essential characters; but it has its limbs connected by thin skin, which they stretch out, as the framework of an umbrella supports its covering. By this singular structure the animal is supported in the air, as by a parachute; but it has not the power of sustaining a continued flight, though it can leap a distance of a hundred yards with a gradual descent. Like the bats, it feeds on insects, and sleeps with its head downwards, suspended by its hind-legs. It is a native of the Indian Archipelago. The other of these aberrant forms is the *Cheiromys*, or *Aye-aye*, which, from the peculiar form of its two lower front teeth, has been ranged with the Rodentia. In its general character, however, it is essentially a lemur; the thumbs of the hind-feet are opposable to the other toes, which is not the case with any truly rodent animal; and approaches to a similar conformation of the teeth are seen in other lemurs. Moreover, it is a native of Madagascar, the centre of this group. It is a nocturnal animal, about the size of a hare: it is said to spend its day in holes in the ground (but these are probably not of its own excavation), and at night to climb trees, from the crevices in the bark of which it picks out worms and larvæ of insects with its long slender fingers.

Bimana.

At the head of the Mammalia, and consequently of the entire Animal Kingdom, stands the order Bimana, implying Two-handed Animals, but in reality composed of but one genus—Man. He may be comprehensively described as a being fitted to live upon almost all kinds of food, and in every part of the earth except those constantly under snow; of an extraordinary intelligence, and tendency to social life; eminent in power over all other animals, and endowed with the greatest ability to turn the objects and forces of physical creation to his own benefit. Besides all this, we believe there is a spiritual being within us, and vouchsafed to no other species, by which we are brought into peculiar relations to the Divine Author of nature, and which will survive the frail tenement in which we live.

In this place we have to consider man solely as a part of the Animal Kingdom. He is distinguished by an erect posture, and by the two fore extremities being fitted for prehension only, while the two hinder are devoted to support. By the upright position his upper extremities are left at entire liberty, whilst his organs of sense are most favourably situated for observation. The hand of man is adapted to a far greater variety of purposes than that of the monkeys in which it is most perfect; its power consists chiefly in the size and strength of the thumb, which can have its tip brought into opposition with that of any of the fingers; and all these are capable of being moved separately. In none of the monkeys can the thumb be opposed to the fingers with any degree of force, and in many their tips cannot be brought into contact; so that, though admirably adapted for clinging round bodies of a certain size, such as the small branches of trees, their hands can neither seize very minute objects nor support large ones. To the hand of man some have attributed his superiority; but it may be safely said, that he owes this to his mind and its instruments conjointly. The hand would be useless without the mind to direct it; and mankind, if handless, would soon be reduced to a very subordinate kind of existence, if not speedily extinguished altogether.

Man, possessed of so remarkable a means of executing that which his mental ingenuity devises, is less provided, in regard both to acuteness of sensibility and to muscular power, than many other Mammalia. His swiftness in running is inferior to that of other animals of his size. The smallness of his face, compared with that of the cranium, shews that the portion of the nervous system connected with the external senses is less developed in him than in most other animals. Accordingly, he is surpassed by many in the acuteness of his sensibility to light, sound, &c. But he stands alone in the power of comparing his sensations, and drawing conclusions from them. Moreover, although none of his senses are very acute in his natural state, they are all moderately so, which is not the case in other animals; and they are capable (as is also his swiftness of foot) of being much improved by practice, especially when circumstances strongly call for their exercise.

This improvability is one of the most remarkable characteristics of the bodily as well as the mental constitution of man. It is owing to a gradual advance in both, that the civilised races now enjoy so much of comfort, and of means of still further elevation. In the processes by which these are attained, we observe a remarkable difference between the character of man and that of other animals. The arts of which these are capable are limited and peculiar to each species; and there seems to be no evidence of a power of invention, or of construction for any purpose, beyond that to which the original and instinctive powers are adapted. Hence it would appear, that there is no proof of any species or race among the lower animals ever making an advance towards an improvement or an alteration in its condition; and where a particular adaptation of means to ends, of actions to circumstances, is made by an individual—as is often the case where some amount of intelligence or rationality exists—the rest do not seem to profit by it.

Man is as much distinguished, then, from the lower animals by his mental as by his corporeal endowments. Yet they are not of a *kind* altogether different from that which we may elsewhere see. In common with the inferior tribes, he possesses strong instinctive propensities, which are kept under control, however, in a well-balanced mind; but when the reasoning powers are undeveloped, as in early childhood and idiocy, the exclusive sway of the instincts is obvious. The more violent passions and emotions are nearly akin to these; and whilst they give great activity to the operations of the mind, it is requisite that they should be duly restrained by the intellect and will. This power of internal regulation is one of the most striking characteristics of the human mind above that of animals, which possess like it reasoning faculties, often to no mean extent, and are actuated by emotions and moral feelings.

One of the most important aids to the use and development of the human mind, is the power of producing articulate sounds, or language; of which, so far as we know, man is the only animal in possession. There is no doubt that many other creatures have certain powers of communication amongst individuals; but these are probably very limited, and of a kind very different from a verbal language.

The more we study the physical and mental constitution of man, the more are we led to the belief, that it is in the adaptation of the whole to a great variety of circumstances that its great perfection consists. There seems scarcely any condition in which he cannot support himself; he is capable of sustaining the lowest as well as the highest extremes of temperature. Furnished with cutting, canine, and molar teeth, he is clearly fitted for a mixed kind of diet; but he can support himself in health and strength on either animal or vegetable food exclusively. At the same time, it is by the demands which his peculiar condition makes upon the exercise of his ingenuity that his mental powers are first called into active operation; and when once aroused, their development has no assignable limit. On a cursory glance at the condition of the inhabitants of different parts of the earth, it will almost always appear that where food and shelter are the most easily obtained, civilisation is the least advanced. Frequently, as in many Eastern nations, a certain progress is early made, and the race then remains stationary for centuries.

The striking differences in colour, in the form of the head and other parts of the body, and in degree of intelligence amongst the different races of men, have caused some naturalists to regard them as constituting distinct species—that is, as being descended from original stocks having corresponding differences from each other. But this notion does not appear reconcilable with the fact, that in each race there not unfrequently exist subdivisions, of which the characters approximate more closely to those of other races than is ever seen among distinct species.* For example, although a characteristic specimen of the Negro race is extremely different from a well-formed European, a series of nations might be traced in Africa whose common origin can scarcely be questioned, and which yet lose one Negro peculiarity after another, until a very close approach is manifest to the character of the white races.

Again, it is to be remarked, that the differences among the races of men are such as are observed in other animals to result from the influence of external causes, or to have a spontaneous origin; whilst in those points which most completely separate him from the species most nearly allied, there is a thorough conformity. This is especially the case in regard to his mental endowments; for similar natural prejudices and impressions, the same feelings, sympathies, and propensities, and intellectual faculties corresponding in kind, if not in degree, may be traced in all of them.

Nevertheless, the different races peopling the earth may be associated into groups, from their greater or less resemblance to each other; these groups having probably been distinct from a very early period, and their members usually having affinities in language as well as in physical conformation. Five of such groups are usually described.

The first occupies Europe and the south-western part of Asia, and may be geographically divided from the second by a line passing eastwards from the Euxine through the Caspian, then following the direction of the Himalaya mountain-range, and descending to the Gulf of Bengal. The two great regions thus separated have been from the earliest periods the abode of two great classes of the human race, differing from each other in manners and social character, as remarkably as the arid and saline plains of Mongolia and the cold desert of Gobi differ from the warm and fertile countries of Southern Asia.

To the western group (commonly termed Caucasian) the name of *Iranian* is applied by Dr Prichard, the highest authority on this subject. The nations composing it people India, Persia, and Arabia, the north of Africa, and nearly the whole of Europe. In the inhabitants of this space, a similar configuration of body may, with few exceptions, be recognised. Of this, the ancient Greeks seem to afford the most perfect model. It is principally remarkable for the roundness of the cranium and the oval form of the face, and for the small proportion which the latter bears to the former, the upper and anterior parts of the brain being chiefly developed. The muzzle does not project, the front teeth of both jaws being perpendicular; the lips are gently turned out, the chin full and rounded. Complexion does not enter into the characters of this group; since it is of all shades, from the white and florid colour of the northern Europeans, to the jet black of many tribes in Libya. In these Indo-Atlantic nations, we find the greatest energy of the intellectual powers and moral feelings, and the greatest susceptibility of improvement by culture. They certainly, therefore, rank highest in the human family. It seems probable that the region of Upper Asia termed Iran, was the primitive seat of those families of nations who have most extensively spread the same type of features.

The nations inhabiting the northern and eastern parts of Asia, with the Finnish nations of Northern Europe, and the Esquimaux of North America, evidently belong to a different group (commonly called the Mongolian), to which Dr Prichard has given the appellation *Turanian*. These are particularly characterised by the form of the skull and face, which seem as if they had been flattened in front; so that the features run together. The cheek-bones project very far sidewise; the nose is small, and flat; the lips rather thick; the chin less projecting. The characteristic complexion of this group is olive; the eyes are usually black; and the hair black, straight, and strong, but thin. The forehead is low and flat. Their stature is generally lower than that of Europeans; and, with greater acuteness of the senses, they exhibit less intellectual power.

The general characters of the Negro races inhabiting the tropical parts of Africa are sufficiently well known. Their complexion and eyes are dark, approaching more or less closely to black; the hair black and woolly. The skull looks as if it had been compressed laterally, so as to cause the face and back-head to project. The forehead is low, narrow, and slanting; the jaws narrow and projecting; the upper front teeth oblique, and the chin receding; the nose is broad and flat; the lips, especially the upper one, thick. It cannot be denied that in these characters the Negro head is intermediate between that of the European and that of the monkey; but it far more nearly resembles the former than the latter. It is a very important fact, also, that it is only in the most degraded African races that we meet with the *whole* assemblage of characters regarded as distinguishing the Negro; and that in others we find so strong a tendency towards a higher character, that it would be difficult to distinguish many individuals among them from others that might be selected from the Iranian race. The influence of climate, and other external circumstances, on the physical and mental development of the human body, is nowhere more evident than when the degraded nations of the Guinea coast are contrasted with the intelligent Caffres of the south or the civilised Ashantees to the north. There can be little doubt, then, that no decided lines separate the African from the European races; and that the former may, in process of time, be brought up to the same intellectual and moral standard with the latter.

According to Dr Prichard, the Hottentots and Bushmen, inhabiting the south of Africa, must be regarded as constituting a distinct group, in which human nature

is exhibited in its most degraded form. There is a remarkable admixture in their physiognomy of the characters of the Negro and Turanian races. The face is extremely flat; the nose has scarcely any perceptible ridge, and its extremity is greatly widened; the eyes are placed very obliquely, as in the Chinese; the chin is prominent, but very narrow; the complexion is like that of a Negro, diluted with yellow; the hair grows in separate tufts, which spontaneously twist together. In their language, the Hottentots seem to have no affinity with the other nations of South Africa which had a Negro origin; and they live in a more destitute and miserable condition than any other inhabitants of this continent.

The aboriginal nations of America, excluding the Esquimaux and some other tribes, form a well-marked division of the human family, bearing a strong general resemblance to each other in their most remarkable characters, both physical and moral. As in the Iranian division, the complexion varies extremely; but in general a reddish or copper hue prevails. The form of the head more resembles that of the Turanian group than any other.


Caucasian.


Arab Moor.


Mongolian.


Otto Indian of N. America.


Negro (pure type).


Malayan.


Central American Indian.


Bushman (of S. Africa).


Native of Tasmania.


Native of Tierra del Fuego.

The Indian and Polynesian archipelagoes are inhabited by a great variety of nations, which have probably had mixed origins, and which it is difficult, therefore, to refer to any single group. Two races, however, appear to be decidedly distinct from the rest. One of these consists of the genuine Papuas, or woolly-haired inhabitants of the interior of New Guinea and the adjacent large islands. These bear a strong resemblance to the people of Madagascar. Their hair is less woolly, is longer and thicker than that of the Negroes, but is very different from the lank hair of the Malays and other races. The other, that of the Alfourous, appears to have constituted the primitive population of the Eastern Archipelago, but is now nearly confined to the interior of Australia. The hair is not woolly, but hard, black, and thick. The countenance is flattened, and the nose so wide that the nostrils are almost transversely placed. The lips are thick; the mouth wide; and the teeth projecting. The colour of the skin is of a smoky black, never very deep. The stature is usually below the mean; and the limbs seem of disproportioned length. Their physical and mental development appear altogether extremely low.

NATURAL PHILOSOPHY—MATTER AND MOTION.

As man contemplates the bodies that make up the universe, and the endless movements and changes they undergo, he becomes impressed with the conviction that these *phenomena* (appearances), as they are called, are not simply a collection of individual things ruled by chance, but that there are fixed connections—in other words, order and uniformity among them; and he feels irresistibly impelled to trace out these connections wherever they can be discovered. In this pursuit we have Natural Philosophy in its widest sense.

When we have found out an unchangeable link of connection between two or more phenomena, we are said to have discovered or established a *law* of nature. It is observed, for instance, that whenever matter is heated, it becomes enlarged in bulk; it is therefore recorded as a law of nature, that 'heat expands bodies.' When, again, we can shew that some other phenomenon, seemingly widely different, is really, though indirectly, caused by the operation of the same law, we are said to *explain* that phenomenon. Thus we explain the fact that a clock is apt to go slower in summer than in winter, by first establishing that a clock goes slower the longer the pendulum is, and then inferring from the law of expansion by heat, that the pendulum must be longer in summer than in winter.

Some phenomena depend upon the peculiar kind of substance of which the body manifesting them is composed, and consist in changes of its constitution; as when sulphur, at a certain temperature, takes fire—that is, unites with the oxygen of the atmosphere, and forms a suffocating gas, changing permanently its constitution and properties. The facts of this class form the separate science of *Chemistry*. Organised bodies—that is, plants and animals—also manifest a peculiar set of appearances which are summed up in the word *life*. The consideration of *vital* phenomena belongs to the department of science called *Physiology*, sometimes *Biology*.

But there is a large and important class of phenomena of a much less special kind, and which belong to matter in general, and to all bodies composed of it, whatever be their peculiar constitution, and whether organic or inorganic. Thus, a stone, a piece of sulphur, a plant, an animal, all fall to the earth if unsupported, are all capable of being divided into small parts, all reflect more or less light, &c. It is the investigation of universal laws of this kind, where no change of constitution is concerned, that constitutes Natural Philosophy, in its narrower sense; for which the term *Physics* is now more generally used, as being more precise. Of those physical phenomena, again, some have a higher generality than others, and it is these most general laws of the material world that naturally fall to be discussed in this introductory treatise. They may be arranged under the heads of *General Properties of Matter*, *Motion and Forces*, and *Heat*.

GENERAL PROPERTIES OF MATTER.

Matter, or that which composes all bodies, has certain *properties*; by which is meant, that it has the power of making certain impressions upon our senses, or of exciting in us *sensations*. Through these sensations we are said to have a *perception* of matter and bodies; but as to what matter is in itself, beyond its power of affecting our senses, we know nothing. The something, whatever it is, in which this power is conceived to reside, is called *substance*. Some philosophers deny the existence of anything beyond the properties; but though we have no direct evidence of anything else, it is difficult, if not impossible, to get rid of the notion, that there is a substance in which the properties inhere. So far as natural science is affected, the question is of no moment; what really concerns us is how matter appears and acts, and not what it is. The more important of the properties of matter are—Impenetrability, Extension, Divisibility, Inertia, Porosity, Compressibility, Elasticity, Attraction, States of Aggregation, Malleability, &c. We shall describe and illustrate them in succession, classing such qualities together as seem to be naturally connected.

Impenetrability is that quality of bodies by virtue of which each occupies a certain portion of space, to the exclusion of all other bodies; it expresses the fact that two bodies cannot be in the same place at the same time. The term impenetrability is not a happy one, though it is difficult to find a better. In the popular sense of the word, matter is anything but impenetrable. The hand can be thrust into water, a nail can be driven into wood, and even the hardest substances are pierced by others that are more or equally hard. But all these are instances merely of displacement, or of removing part of one body to make room for another. There is no wood where the nail is, nor are the particles of the removed wood driven into one another, so to speak; they are merely forced closer together, as those of a sponge are when squeezed. That the most movable and unsubstantial substances, when displacement is prevented, occupy space as effectually as the most solid, is seen in a blown bladder, or in an air-cushion. This property of air is taken advantage of in the diving-bell. An easy illustration is got by pressing a common glass tumbler, mouth downwards, into a vessel of water. Though the water ascends more or less according to the depth, the air makes good its claim at ordinary depths to the greater part of the space, and even though sunk to the bottom of the sea, the water would never get quite to the top. If a small lighted taper, floating on a bit of cork, be carried down with the tumbler, the singular appearance may be beheld of a light burning under water.

Extension or *Magnitude*, and *Form*.—Magnitude or size is one of those simple ideas that do not require or admit of explanation, because there is nothing simpler to explain them by. It is chiefly by their extension that bodies make themselves known to our senses; and when we try to think of those minute particles of matter that elude the senses, we can conceive them only as extended, or having a certain magnitude. Bodies are extended in three directions, or have three *dimensions*—namely, length, breadth, and depth. Width is the same dimension as breadth; and for depth we often use height, and sometimes thickness. The way in which these dimensions are bounded gives each body its peculiar form or shape. This is equally true of a block of stone, a sheet of paper, a hair, a particle of dust.

Divisibility.—There is no known limit to the divisibility of matter. A chip of marble may be broken from a block, and that chip may be crushed to powder. The smallest particle of this powder discernible by the naked eye, when examined by the microscope, is seen to be a block having all the qualities of the original marble, and capable, by finer instruments, of being divided into still smaller blocks, which may be again divided; and so on, with no other limit than the fineness of our senses and instruments.

The unlimited degree to which matter may be

comminuted is yet more strikingly seen in other ways. The goldbeater produces leaves, of which there are 282,000 in a pile of an inch deep. In making the gilt silver-wire used in embroidery, a rod of silver is covered with a small proportion of gold, and then drawn out to a fine wire, in which the gold retains the same proportion to the silver as at first. A portion of this wire, on which the gold is only the 482,000,000,000th part of an ounce, may be seen by a microscope to be covered with a continuous coating of the metal, having all the appearance of solid gold. The thinness here far exceeds that of goldleaf.

Still more minute must be the division when a substance is dissolved in a liquid, or water rises in vapour, since the particles in this case become so minute as to be invisible with the most powerful magnifiers. The microscope, again, has revealed the existence of animals, a million of which would not occupy more space than a grain of sand. Yet these animalcules, as they are called, have limbs and organs, and display all the appearances of vitality. How shall we conceive the smallness of the tubes or vessels in which their fluids circulate, and the minuteness of the particles of matter composing these tubes and fluids!

Divisibility thus extends far beyond the limits perceptible to the senses. Are we, therefore, to assume that it is without limits—that matter is infinitely divisible? This would be a rash assumption. On the contrary, there are many reasons for believing that there is a limit somewhere, and that there are ultimate particles, of a determinate size and shape, incapable of further subdivision. These assumed ultimate particles are called *atoms*, from a Greek word signifying indivisible. Their existence is inferred from a number of facts connected chiefly with crystallisation and chemical combination, which cannot be otherwise explained.

But whether the ultimate component particles of bodies have a fixed size and shape or not, we know that they are *indestructible*. This is not, indeed, what a first impression suggests, for nothing is more common than for bodies to decay, dissolve, evaporate, and disappear. But it can be proved that in no case is anything lost. The structure or form is destroyed, the materials remain. Water, mercury, and many other substances disappear in invisible vapour when heated; but if the vapour is carefully collected and cooled, the water or mercury reappears without loss of weight. The substance of the coal burnt in our fires is not annihilated; it is only dispersed in the form of smoke or particles of soot, gas, and ashes or dust. Bones, flesh, and other animal substances, may in the same manner be made to assume new forms, without losing a particle of the matter which they originally contained.

The decay and decomposition of animal and vegetable substances beneath the surface of the earth fertilise the soil, which nourishes the growth of living plants; and these, in their turn, form the nutriment of animals. There is thus a perpetual change from death to life, and from life to death, and as constant a succession in the forms and places which the particles of matter assume. Nothing is lost, and not a particle of matter is struck out of existence. The same matter of which every living animal and every vegetable was formed in the earliest ages, is still in existence. As nothing is lost or annihilated, so it is probable that nothing has been added, and that we ourselves are composed of particles of matter as old as the creation. In time, we must in our turn suffer decomposition, as all forms have done before us, and thus resign the matter of which we are composed to form new existences.

Inertia or *Inactivity*.—This is one of the most important qualities of matter, and deserves careful consideration from the number of phenomena it enables us to explain. It is at the foundation of nearly all that concerns motion and forces. The term inertia or inactivity is meant to express the fact, that an inorganic body has no power to change its state. If it is at rest, it cannot put itself in motion; if it is in motion, it cannot bring itself to rest; any change must come from some external cause. It hardly gives a correct notion to say that bodies are quite passive to a change of state; for they *resist* the change, with a force depending upon the mass of matter they contain and the amount of motion sought to be given to them or taken away. The expression *vis inertiæ*, force of inactivity, though involving a sort of contradiction, is sometimes used to indicate this quality of resistance. No one term conveys all that is meant; *persistence* has been suggested as less objectionable than inertia, inactivity, or passiveness. Bodies may be said to have a tendency to persist in their actual state, whether of motion or rest.

The following instances illustrate the action of this property of matter:—A great force is necessary at first to set a vehicle in motion; but when once this is effected, it goes onward with comparative ease; so that, in fact, a strong effort is necessary before it can be stopped. If a person be standing in it when it is suddenly set agoing, his feet are pulled forward, whilst his body, obeying the law of inertia, remains where it was, and he accordingly falls backwards. On the other hand, if the vehicle be suddenly stopped, and the individual be standing in the same position as formerly, the tendency which his body has to move forward—for it acquired the same motion as the carriage by which it was borne along—will cause him to fall in that direction. Casualties of this description frequently occur to persons on horseback, who are thrown over the necks of their steeds, or fall behind them, according as the animal stands still suddenly, or starts off unexpectedly. A man jumping from a coach at full speed will certainly fall prostrate on the ground, if he leaps down as if he were descending from a body at rest, to one which is in the same state; for when he makes the attempt, his body has the same motion as the coach; and when the feet arrive at the ground, the motion in the lower part is arrested, while it continues in the upper part; and thus he finds himself thrown down.

Another familiar example of the inertia of matter is this:—Upon the tip of the finger let a card be balanced, and a piece of money—say a shilling—laid upon it. Let the card then be smartly struck, and it will fly from beneath the coin, leaving it supported upon the finger. This arises from the inertia of the metal being greater than the friction between it and the card.

The process of beating a carpet, or dusting a book, rests on the same principle as the experiment with the shilling and the card. The carpet being struck, is suddenly put in motion, while the particles of dust remain where they were, their inertia being sufficient to overcome the slight force with which they adhere to the surface of the carpet. When a dusty book is struck against a table, the book and the dust are first brought into rapid motion together, and the book being then arrested by the table, the dust continues in motion by its inertia, and is thus detached.

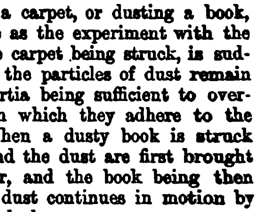


Fig. 1.

Coursing, or hare-hunting, affords a striking illustration of inertia. In that field-sport the hare seems to possess an instinctive consciousness of the existence of this law of matter. When pursued by the greyhound, it does not run in a straight line to the cover, but in a zigzag one. It *doubles*; that is, suddenly changes the direction of its course, and turns back at an acute angle with the direction in which it had been running. The greyhound being unprepared to make the turn, and therefore

unable to resist the tendency to persevere in the rapid motion which it has acquired, is impelled a considerable distance forward before it can check its speed, and return to the pursuit. But, in the meantime, the hare has been enabled to shoot far ahead in the other direction; and although a hare is much less fleet than a greyhound, by this scientific manœuvring it often escapes its pursuer.

It is a common impression with those who have never reflected upon the subject, that bodies are more inclined to rest than to motion. This arises from the fact, that while no body begins to move or increase its speed, without some cause for the change being apparent, all the motions that come within our observation on the surface of the earth do actually come to an end, most of them gradually, and without any very apparent cause. Thus the notion is begotten that rest is the natural state to which all matter, when left to itself, seeks, as it were, to return. But a little consideration shews us that the retardation and stoppage of motion are as dependent on causes as its beginning is. A ball rolled on the rough earth soon stops; on a wooden floor, it continues longer; and on smooth ice, longer still. This shews that one cause of the arrest of terrestrial motions is friction. Another constant impediment is the resistance of the air. A common top continues to spin a greater length of time in a space from which the air has been extracted by an air-pump, than it usually does. A pendulum set in motion in an exhausted receiver, will continue to swing, without the help of clock-work, for a whole day, having nothing to resist its motion but the small amount of friction at its point of suspension. Finding thus that motion is prolonged in proportion as we diminish obstructions to it, though we can never completely remove them, we conclude, that if they were removed, motion once begun would go on for ever.

It is in the heavenly bodies, however, that we find complete proof of this truth. They move without friction, and unresisted by any fluid like air, and no observation can detect any slackening of their speed; they retain the amount of motion they had from the beginning.

Compressibility, Contractibility; Expansibility, Dilatability.—When a body is forced by mechanical pressure into less space than it previously occupied, it is said to be *compressed;* when any cause not mechanical, such as loss of heat, causes its volume to diminish, it is said to be *contracted.* *Expansion* and *dilatation* are used to express enlargement of volume or bulk. Now, all bodies whatever are liable to these two opposite kinds of change—to have their volume, from a variety of causes, at one time enlarged, at another time diminished, and that without any addition to, or deduction from, the matter composing them. To say nothing of sponge, cork, wood, &c., the compressibility of which we experience every day; even those substances which we consider as types of solidity, are compressible. A piece of iron, when squeezed in a vice or hammered, loses in bulk, and becomes more compact.

The most compressible substances are air and other gases. A moderate pressure will force a quantity of air confined in a vessel into half its volume; and as the pressure is increased, the volume goes on diminishing almost without limit. By pressure and cold combined, several gases have been reduced to the liquid form. Compared with gases, or even solids, liquids have little compressibility. For all practical purposes, they are assumed to be completely incompressible, and water is so considered in hydrostatics and hydraulics. But experiment has proved this not to be strictly true; for, when submitted to a pressure of 15,000 pounds on the square inch, water is found to lose 1-20th of its volume.

Expansion or dilatation is chiefly seen in the case of heat being applied to bodies (see page 205). Gases are unlimitedly dilatable. If a room were completely exhausted of air, and a cubic inch of any gas introduced, it would instantly diffuse itself through the whole room, so that no space, even the smallest appreciable, would be completely void. The only reason why the air of our atmosphere does not diffuse itself throughout space, is that it has weight, which sets a limit to its dilatation.

Elasticity.—Some bodies, when compressed, recover their former size when the pressure is removed. Such bodies are called *elastic;* and those which remain as the compressing force put them, are *non-elastic.* Air and other gases afford the best examples of elasticity. Caoutchouc, ivory, and steel, are among the most elastic of solid substances. But no solid body is perfectly elastic, nor are any completely non-elastic; so that elasticity may be considered as general a property of matter as compressibility. The cause of elasticity is not well understood; it is supposed to be some peculiar relation between the forces of attraction and repulsion among the atoms.

Porosity and *Density.*—In common language, a pore is a small hollow space or interstice between the particles of a body, large enough to be seen, or to admit the passage of liquids or gases. In this sense, some substances, such as sponge, wood, sugar, &c., are called *porous,* and others are contrasted with them as *solid.* But experiment and reflection lead us to the conclusion that all bodies are porous. We have seen that bodies are made up of indefinitely small atoms; and the fact that all bodies admit of compression and expansion, makes us believe, that in no case do these atoms fill the whole space occupied by the body, but have interstices of greater or less size between them; so that when a body is compressed, its atoms are only more closely packed. There is nothing, then, that is not porous, in this sense; and one body is more dense or solid than another, only because it is less porous. *Density* thus means the comparative closeness of the atoms of a body; and a dense body contains, bulk for bulk, more atoms, that is, more matter, than one that is less dense, or, in other words, more porous. As weight depends upon the quantity of matter, density and weight thus go together.

In comparing the densities of different substances, that of distilled water is taken as a standard, and called 1. If a cubic inch, then, of any substance weigh twice as much as a cubic inch of water, its comparative density is expressed by 2; and this is generally called its *specific gravity.* The following table exhibits the specific weights of a few of the more familiar substances :—

Platinum, coined, .	22·100	Porcelain, china, . .	2·384
〃 wire, .	19·267	Sulphur, natural, .	2·033
Gold, coined, . .	19·325	Ivory, ...	1·917
Mercury, . .	13·598	Boxwood, ...	1·330
Lead, ...	11·352	Oak, old, . . .	1·170
Silver, . . .	10·474	Amber, ...	1·078
Copper, hammered, .	8·878	Mahogany, . . .	1·060
〃 fused, .	7·788	Milk, ...	1·030
Steel, ...	7·816	Sea-water, . . .	1·026
Iron, wrought, .	7·788	Water, distilled, .	1·
〃 cast, . . .	7·207	Claret, ...	·994
Tin, ...	7·291	Alcohol, absolute, .	·793
Antimony, . . .	6·712	Linseed Oil, . . .	·953
Diamond, . . .	3·520	Ash-wood, dry, . .	·644
Flint Glass, . . .	3·375	Beech, dry, . . .	·590
Marble, ...	2·873	Cork, ...	·240

Porosity, even in the sense of admitting the passage of liquids and gases, exists to a greater extent than is generally supposed. If a wooden cask full of spirits is sunk in water for a time, the cask will be found filled with water, and the spirits gone. The spirits escape, and the water enters through the pores of the wood. A hollow globe of gold filled with water, and closed with a screw, was once submitted to great pressure; when the surface of the gold became covered with dew, the water being forced through its pores. The important process of filtration depends on porosity.

Attraction and *Repulsion.*—The term attraction is applied to a great many phenomena, which we must regard as of different kinds, or produced by different causes. The force, whatever it is, that makes a stone

fall to the earth, is called the *attraction of gravitation*, because it is the cause of *gravity* or weight. Sir Isaac Newton demonstrated that the same force acts on the moon, drawing it towards the earth; and on the earth, drawing it towards the sun: or rather, that the attraction between any two heavenly bodies is mutual, making them approach each other. It is now established as a fundamental law, not only of our globe, but of the universe, that every atom of matter is attracted towards every other atom. The effects of this law, in causing the fall of bodies and weight, will be considered under Terrestrial Gravity in this number. (See also ASTRONOMY.)

When a loadstone or a magnetic needle is brought near to a piece of iron, the two bodies, if free to move, will come together and adhere to each other. Also, if a stick of sealing-wax is rubbed with silk, it will draw a light feather to it. These two forms of attraction—the *magnetic* and the *electric*—will be particularly described in the number on ELECTRICITY and MAGNETISM.

The kinds of attraction already mentioned act between bodies at a distance, as well as near. We know, for instance, that gravitation retains Neptune in his orbit at the distance of 2854 millions of miles from the sun. But there are forces at work in matter which act only at insensible distances, and between the adjacent molecules; they are hence called *molecular forces*. These play an exceedingly important part in nature, being the causes of a number of the most interesting phenomena. They are spoken of under the names of Cohesion, Adhesion, Repulsion, and Chemical Attraction.

Cohesion is that force that binds together particles of the same kind of matter, so as to form masses or bodies. Without some force to hold the atoms or molecules together, we could not have bodies, but mere heaps, as of sand. Some of the ancient philosophers imagined that atoms were provided with hooks, that made them stick to one another. But as we now know that distant bodies act upon one another with nothing between—draw one another, as it were, without ropes—we can conceive atoms holding one another, when near, without hooks. Cohesion acts only when the atoms are at distances so minute as to be insensible to us: when removed beyond that distance, it has no influence whatever; and when the atoms of a solid body are once separated, it is in most cases impossible to bring them near enough again to make them cohere. Two fresh cut surfaces of lead may be made to cohere with some force; but a slight film of rust or of grease will completely prevent the necessary nearness of the metallic molecules. Interrupted cohesion is easily restored when the body is in a fluid or half-fluid state, owing to the mobility of the molecules; as when a broken stick of sealing-wax is mended by melting the two ends and pressing them together, or two pieces of iron are joined by welding.

The three *states of aggregation*, as they are called—that is, the *solid*, *liquid*, and *aëriform*—are owing to differences in the strength and manner of acting of cohesion. It is commonly said that its force is greatest in solids, less in liquids, and altogether wanting in gases. But this account does not explain all the differences of these states. If the smallest quantity of air, or any other gas, is admitted into the exhausted receiver of an air-pump, it does not remain at the bottom, but spreads itself instantly and uniformly through the whole space, as if its particles wished to remove from one another as far as possible. There seems no limit to the space over which the smallest portion of gas will thus spread itself, so that it shall be found in every part of it. We cannot help inferring from this, that the atoms of a gas, instead of attracting, actually *repel* one another with a force sufficient to overcome their own weight—for gases have weight as well as solids and liquids. The dilatation of solid bodies by heat, and the recoil of elastic bodies after compression, would also seem to imply some repulsive force at work.

Again, some gases, when compressed with great force, have their atoms forced so near that they become liquid; and in this condition they are seen to cohere and form drops, thus shewing that they are not destitute of attractive force. The natural conclusion from these and other observed facts is, that among the atoms of all bodies there are two opposing forces at work—an attractive force, and a repulsive force—that when attraction considerably predominates over repulsion, a solid body is the result; when there is almost a balance of the two forces, we have a liquid; and when the repulsive force has the upper hand, we have a gas. Many substances are seen to assume all three forms in turn. Liquid water turns at one time into solid ice, at another into vapour or steam. Greater extremes of cold and heat have the same effects on mercury. Several gases, by applying great pressure and cold, have been rendered liquid, and one at least even solid; and thus it becomes probable that all substances are capable of existing in any one of the three states under certain conditions.

From the fact that the increase of heat regularly increases the energy of repulsion, heat and the repulsive force may be considered one and the same thing. The subject of HEAT will be more fully considered under a separate head.

In solids, the cohesion is exerted in such a way as not only to keep the atoms from separating, but also to retain them in the same relative position; in liquids, on the contrary, the atoms, while still kept from separating, are allowed to move or slide freely upon one another in all directions. This free motion of the molecules upon one another, rather than want of cohesion, is the grand characteristic of liquids as well as gases; it is one of the causes of drops being spherical. Differences of cohesion give rise to such distinctive qualities of bodies as the following:

Hardness.—This quality depends not so much upon the force with which the particles resist separation, as upon their resisting displacement or alteration of relative position. Softness implies the opposite. Hardness is tested by one body scratching another. It does not correspond with density. Thus, glass scratches gold, and even platinum. Steel has its hardness modified by tempering.—*Malleability* is a distinguishing quality of some metals, and means the capability of being extended into thin plates or leaves by hammering. It depends upon the union of softness and tenacity; the particles shift their position without separating. The chief malleable metals are gold, silver, copper, iron, zinc at the temperature of boiling water, and lead. Gold may be reduced to leaves so thin as to be translucent.—*Ductility* is the property by which a metal admits of being drawn into wire. The most malleable metals are not the most ductile. Iron is much more ductile than tin or lead, though not so malleable. The most ductile metal is platinum.—*Tenacity* expresses the quality by which a body resists being torn asunder, and depends upon the intensity of the cohesive force. It is not the opposite of *brittleness*. Brittleness is associated with hardness and unyieldingness, except within narrow limits. Glass is brittle—that is, is easily broken by bending or crushing—but a glass-rod will sustain a great weight without being *torn* asunder. Thus it is both brittle and tenacious. Fibrous substances—as silk and flax—possess great tenacity. The most tenacious of all substances is steel.

Adhesion, or, as it is sometimes called, heterogeneous cohesion, is the term applied to the attraction which makes two different substances stick to one another by their surfaces. Cohesion acts between the particles of the same kind of substance; adhesion, between dissimilar kinds of matter. Though the same force probably causes both, yet the effects are so different that it is convenient to consider them separately, and give them different names.

Adhesion between solids.—Particles of dust on an upright pane of glass, chalk-marks on a wall, sealing-

wax on paper, cement, are all instances of adhesion between substances of different kinds. Two polished plates of brass laid on one another, require considerable force to separate them. (Strictly speaking, this is a case of cohesion; but where the attraction is between the surfaces of two distinct bodies, it may be considered as adhesion, notwithstanding that the matter is of the same kind in both.) If one of the plates be of steel, the adhesion will be less; and generally similar surfaces adhere more than dissimilar. Adhesion between surfaces is the chief cause of friction, and unctuous substances are interposed to prevent it.

Adhesion of liquids to solids takes place much more readily than that of solids to solids, because in the case of a liquid and a solid the surfaces come into more complete contact. When the hand or a rod of metal is dipped into water, a film of the water adheres to the surface, and is borne up against its own weight; nor can any force shake it all off. Plunge a bit of gold, or silver, or lead, into mercury, and a portion of the mercury will in like manner adhere. Wherever we have *wetting*, we have a case of adhesion of a liquid to a solid. It is the cause that in pouring water over the edge of a vessel, the water is apt to run down the side of the vessel rather than fall perpendicularly.

But liquids do not always wet solids, or adhere to them. A rod coated with grease, or the wing of a water-fowl, remains dry when plunged in water. Mercury does not adhere to a porcelain cup, or to a rod of iron or platinum. The explanation is simple. There is in every case an attraction between the solid surface and the liquid, but it is opposed by the attraction of the particles of the liquid for one another, and there can be actual adhesion only when the first is stronger than the other.

Capillary attraction is only a particular effect of adhesion. A tube with a small bore, like a hair, is called a capillary tube, from *capilla*, the Latin word for a hair. If the end of such a glass-tube is dipped in water, the water is seen to rise in the tube above the level of the rest of the surface. In a series of tubes of different diameters, the liquid ascends highest in the smallest; or the heights are inversely as the diameters. Water will be seen to rise in a similar way between two glass-plates placed as in the figure, with two of the upright

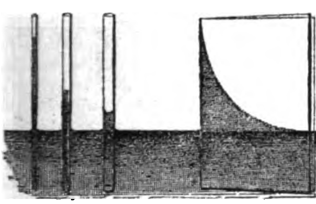


Fig. 2.

edges touching, and the other two slightly apart. The sustained film rises higher as the plates approach, assuming the form of a particular curve. The fluid rises also slightly on the outside of the tubes and plates, and the surface of the sustained column within the tube is seen to be hollow like a cup.

But liquids do not always ascend in narrow tubes or spaces; it is only when they wet the solid substance that they do so. If a greasy glass-tube is dipped in water; or, still better, if a clean glass-tube is dipped in mercury, the liquid inside, instead of rising, sinks below the general level; the surface of the column, too, becomes convex instead of concave.

The rise or the depression depends upon the adjustment between the forces of adhesion and cohesion, as in the case of wetting. When the liquid wets the tube, the particles next its surface have part of their weight taken away or supported by adhesion, and thus a longer column is required to balance the pressure of the rest of the fluid. In cases where the cohesive attraction of the liquid particles within the tube for one another is too strong to permit them to adhere to its surface, that cohesion tends to draw them away from it, and downwards; while the tube prevents them from receiving the support they would have from the liquid particles around them, if it were not there. 'Mathematicians have shewn, that if the adhesion between the solid and the liquid be equal to half the cohesion of the particles of the fluid, the surface at the point of contact will be neither elevated nor depressed; if the adhesion between the two be more than half the cohesion, elevation will occur; and if it be less than half, the surface will be depressed and convex.'

Capillary attraction is exemplified in many familiar appearances, and plays an important part in nature. If a piece of sponge or a lump of sugar be placed so that its lower corner touches the water, the fluid will rise up and wet the whole mass. In the same manner, the wick of a lamp will carry up the oil to supply the flame, though the flame is several inches above the level of the oil. If one end of a towel happens to be left in a basin of water, while the other hangs over below the level of the water, the basin will be emptied of its contents; and, on the same principle, when a dry wedge of wood is driven into the crevice of a rock, and afterwards moistened with water, it will absorb the water, swell, and sometimes split the rock.

A striking illustration of this subject is given thus:—Place a wine or drinking glass on a book on the table, and set another close by it, so as to be on a lower level. Pour some water and some oil into the higher glass; then moisten a piece of cotton-wick in water, and place it so as to form a bridge between the two glasses, with an end reaching near the bottom of each. The water, which was below the oil in the one glass, will in an hour or two be found transferred to the other, leaving the oil behind. If the wick be moistened with oil, the oil will be transferred, leaving the water.

When two light bodies, such as two bits of cork, are left to float on water, near each other, they soon come together, moving at last with a rush. This is sometimes given as an example of the gravitation that draws the planets to the sun; but it is really owing to this attraction of adhesion that we are considering. When the liquid wets the floating bodies, it rises slightly all round them, and this sustained liquid hangs as a weight on them on all sides. So long as it rises equally, there is no motion; but when the bodies come near each other, the space between them becomes like part of the inside of a capillary tube, the water rises higher on the near sides than on the opposite sides, and the bodies move towards the sides that are most strongly pulled. When the floating bodies are not wetted by the liquid, there is a semblance of repulsion between them and it; the surface between the two bodies is depressed, and they are pushed together by the greater repulsion on the outside. If one of two bodies floating on water is smeared with oil, so as to prevent the water from adhering, instead of coming together, the two will recede from each other, for reasons analogous to the above.

Endosmose or *Osmose.*—Connected with capillary attraction is *endosmose*. If two liquids be separated by a piece of ox-bladder, the one below the membrane being pure water, the other above being a solution, say of carbonate of soda, the water will pass through the membrane against gravity, and raise the solution above its former level. A smaller portion of the solution finds its way into the water. This remarkable phenomenon is known as *endosmose* and *exosmose*, or simply as *osmose*. It is not yet fully understood, but is believed to play a part in the passage of the fluids through the membranes of living animals and plants.

Adhesion between two Liquids.—The lower half of a tube may be filled with water, and the top with alcohol

or spirits, with little disturbance at first; but after a time the two liquids will be found equally *diffused*—part of the heavier liquid rising up, and of the lighter being drawn down, by the force of adhesion between the two. Where there is no adhesion between two liquids—as in the case of water and oil—they do not diffuse or mix.

Adhesion between Solids and Gases.—Dry iron filings, and even small needles, when gently laid on the surface of water, will float, though eight times heavier than the water, because each has a film of air adhering to it so strongly, that even when it does sink, it carries a portion of the air along with it. In making barometers, it is found that air adheres so firmly to the surface of the glass, that the mercury must be boiled in the tube before it can be expelled. Some porous solids, such as charcoal, absorb air and other gases to an amount many times their own bulk, the force of adhesion condensing the gases on the surface of their molecules. When a lump of sugar is dropped into a cup of tea, the atmospheres of air which surround the particles do not quit them till they are dissolved; bubbles are seen rising till all the sugar has disappeared.

Chemical attraction is a molecular force, whose effects are of a different kind from those of cohesion. If we divide a piece of marble by breaking it into parts, however small, each part is still marble. But the chemist takes it to pieces in a different way. Out of a piece of marble he will produce three distinct substances, altogether unlike the original body—a metal not unlike silver, a black body called carbon, and a gas resembling air. Most of the substances of which our earth is made up are thus composed of two or more different substances. When the chemist tries still further to analyse, or take to pieces any of the three substances he found in the marble, he finds he cannot; out of the carbon he can make nothing but carbon, and so with the others. When a substance thus resists being divided into other substances, it is said to be a simple substance or *element*. Of these elements there are in all about sixty known; and these combine in unions of two, three, or more, to form most of the bodies that we see around us. Thus, water is composed of two gases like air in appearance; vermilion, of sulphur and quicksilver. Such unions are chemical unions, and the attractive force that produces them is *chemical attraction*. Cohesion and adhesion produce unions, but they leave the united substances with their qualities unchanged; chemical attraction, in uniting two substances, changes their properties, and produces a new substance, with new properties. The investigation of changes that thus alter the constitution of bodies, belongs to the science of CHEMISTRY.

MOTION AND FORCES.

Motion is change of place, and its opposite is rest. Motion in any one body has always reference to the place of other bodies, and various distinctive terms are used indicative of this reference. A man sitting on the deck of a ship has a *common* motion with it; if walking on the deck, he has *relative* motion to the vessel. *Absolute* motion means change of place with respect to space itself. But we have no means of marking a fixed point in space, and therefore can never observe such a motion; we know only relative motions. As little do we know of absolute rest. The earth is in constant rotation and also revolution round the sun; and the sun himself is in motion, we know not whither. Motion, and not rest, is the great law of the universe.

Velocity, or speed of motion, is measured by the space passed over in a given unit of time; as when we say that a man walks three miles an hour; or that sound travels 1120 feet in a second. The velocity is *uniform*, when equal spaces are always passed over in equal times; it is *accelerated*, when gradually increased, and *retarded*, when gradually diminished. If the increase or diminution is equal in equal times, the motion is said to be *uniformly accelerated* or *uniformly retarded*. *Force* is any agency that produces motion in a body; when the body is not free to move, the force exerts a *pressure*. Force and pressure are often used indifferently; and weight being the kind of force with which we are most familiar, the amount of a force or pressure is usually expressed in so much weight; as ounces, pounds.

A body when put in motion acquires the power of setting other bodies in motion: in other words, it acquires force; and this force of a moving body is called its *momentum* or *quantity of motion*. Momentum does not depend upon velocity alone. Of two balls moving at the same rate, but the one having twice the mass of the other, the larger will have just twice the force or momentum. Momentum, then, is made up of velocity and quantity of matter taken together. To get the comparative momenta of two bodies in numbers, we multiply the weight of each by its velocity. If two balls of 6 and 8 pounds move, the first 100, the other 50 yards in a second, the momentum of the first will be to that of the second as 6×100 to 8×50, or as 600 to 400, or as 3 to 2.

LAWS OF MOTION.

The leading truths respecting the movements of bodies have been summed up in the shape of a few axioms, or propositions, which were first put into shape by Newton under the name of *Laws of Motion*. Various modifications of these laws have been proposed, with a view of rendering them more explicit. We shall give them as laid down by Newton, and then follow them up with observations on each.

1*st*, Every body must persevere in its state of rest, or of uniform motion in a straight line, unless it be compelled to change that state by forces impressed upon it.

2*d*, Every change of motion must be proportional to the impressed force, and must be in the direction of that straight line in which the force is impressed.

3*d*, Action must always be equal and contrary to reaction; or the actions of two bodies upon each other, must be equal, and their directions must be opposite.

FIRST LAW.

This law is little else than a definition of the property of Inertia or Inactivity. In fact, all these laws are but expansions of the idea of inertia; the facts they state go to make up that idea, or flow from it as consequences. There are three things to be attended to in this law—namely, the *persistency* of matter, both in rest and motion, when not acted upon by external agency; the *uniform* velocity; and the *straight* direction of motion when once begun and left to itself. The first has been already illustrated under the head of Inertia; and when we say that unobstructed motion is naturally *uniform*, we are only repeating in a different form the same truth. If we cannot conceive a body beginning to move without a cause, neither can we conceive a moving body beginning of itself to move faster; and if we believe that when a body in motion is stopped, something external stops it, we must believe that when its motion becomes slower, something is retarding it.

A little reflection brings out the truth of the third point, namely, that motion is naturally *straight*. If a ball projected forward is seen to bend to the right or the left, we infer at once that something interfered with it. That it bends downwards, we know to be owing to the attraction of the earth. Motion therefore requires force to bend it. It might seem at first sight that a body once set amoving in a circle ought, by the law of persistence, to go on moving in the same path when left to itself. But the *same path* is, in this case, not the *same direction*. A body moving in a circle, or any other curve, is continually changing its direction; it is always turning a corner, as it were.

SECOND LAW.

That every change of motion is proportional to the force that produces it, is involved in the way of measuring force, which is by the quantity of motion it gives or takes away. As to the *direction* of the resulting motion, the law requires careful explanation. It has been proposed to express it in the following terms, as less liable to be misunderstood :—'All force, or cause of motion, in any direction, produces its effect in that direction, and in no other.' When the body is previously at rest, it is self-evident that, if unobstructed, it will follow the direction of the force that begins to act upon it; but if it is already in motion in one direction, and a force then comes to act upon it in another direction, it is not so clear what course it will take. To determine the path or line in which a body will move when thus acted upon by more forces than one, is a problem which lies at the foundation of the whole science of mechanics. It is usually treated under the title of the

Composition and Resolution of Motion.

To avoid confusion on this subject, it is necessary to attend to the difference between moving in the same straight line, and moving in the same direction. The ball B in the figure is moving in the same direction, whether it move in the line AC or in any line parallel to AC, as *gf* or ED; in any of these cases it is equally approaching the line CD. In the same way a motion from B towards E, or from *h* towards *i*, or from C towards D, is still in the same direction, because these lines are parallel.

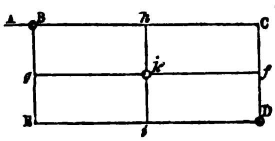


Fig. 3.

Now, let the ball be moving along the line AC with a velocity that would carry it from B to C in two seconds, and when at B let it receive a blow that would carry it from B to E in the same time; the question is, How will the ball now move? This is best understood by supposing it placed not on a plane surface, but in a groove in the upper side of a movable bar lying on a table. The ball being then set arolling at the same rate as before along a groove in the bar AC, let the bar be made at the same time to slide across the table, keeping parallel to itself, and carrying the ball along with it, so as to arrive at the position ED in two seconds. The common motion of the bar and the ball will not in any way interfere with the motion of the ball in the groove, any more than the common motion of a ship and a man on board of it interferes with the man in walking across the deck. The ball will be at the end of the groove at the end of the two seconds, just as if the bar had been at rest; it will therefore, as a result of the two movements, be found at the point D.

If the position of the ball on the table is observed at the intermediate points, it will be found to describe a straight line from B to D; for since we have supposed both motions uniform, the bar will, at the end of the first second, be in the position *gf*, midway between BC and ED, and the ball will at the same instant be halfway from *g* to *f*, at *k*; and it can be proved that *k* is in a straight line between B and D. The same could be shewn as to any intermediate stage.—When both motions are not uniform, the body moves in a curve, as will be seen in speaking of projectiles.

The movable groove is introduced to make the effect of two movements conjoined more readily conceived; to shew palpably, as it were, that a body may be moving in two directions at one and the same time. But if it receive the second impulse by a blow while rolling freely on the table, it will still arrive at D by the same path.

In any case, then, when two forces act upon a body, if we draw two straight lines, AB and AC, in the directions of the two forces, and make the lengths AD and AE in proportion to the velocities that the forces would give to the body if acting separately; then if we draw EF and DF parallel to AD and AE, and join AF, this line, which is called the *diagonal*, gives the direction that the body will move in, and also its velocity; that is, the body acted on by the two forces moves from A to F in the same time in which it would have moved from A to D by the one force alone, or from A to E by the other force alone. A figure thus formed represents both the motions and the forces that produce them, and is called the *parallelogram of forces*. AD and AE are called the *components*, and AF the *resultant*.

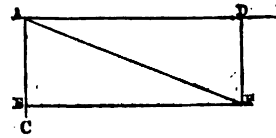


Fig. 4.

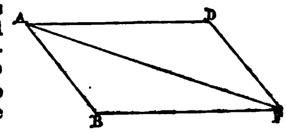


Fig. 5.

In figures 3 and 4, the forces are represented as acting at right angles to one another; but the angle may vary, as in figures 5 and 6, and the learner should observe the effect on the resultants as he draws parallelograms with angles still narrower or still wider.

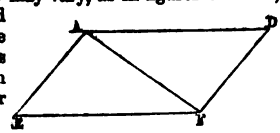


Fig. 6.

We arrive at a similar result if, instead of motions, we consider a set of forces acting against one another so as to prevent motion. When forces thus balance one another, they are said to be in *equilibrium*; and the investigation of such cases forms the part of Mechanics called *Statics* (from a Greek word signifying 'to stand'), while the consideration of force producing motion belongs to *Dynamics* (from the Greek word for 'power').

Two strings fastened to the ring P, and drawn in opposite directions by equal forces, will keep the ring at rest, and the forces are then in equilibrium. The forces A and B, in fig. 7, are represented by two weights, say of six pounds each, suspended over pulleys. Now, it is evident that for one of the two forces we could substitute two other forces, as in fig. 8,

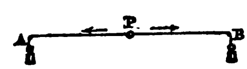


Fig. 7.

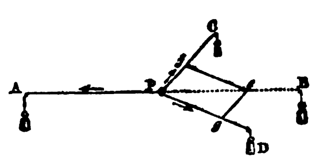


Fig. 8.

pulling in the directions PC, PD, which, if properly adjusted, would still keep the ring at rest. The effect of the two new forces, C and D, is thus equal to the effect of the one force, B, and the force B is said to be *resolved* into the two, C and D.

The exact proportion of the two to each other and to the one original force, may be determined by setting off a length of six parts along P*e*, to represent the six pounds of the original force, and then drawing *ef* and *eg* parallel to PD and PC. We have then a parallelogram of forces. P*f* represents the magnitude of the force C, P*g* that of the force D, and P*e* is the resultant.

As *ge* in the last figure is equal to P*f*, and in the same direction, the two component forces and their resultant are represented by the three sides of the triangle P*ge*; and the resolution of forces is thus often represented by the half of the parallelogram of forces, to save drawing the whole.

The following is an example of the resolution of forces:

Let TP be a ship, SL its sail, WA the direction of the wind, and let the length of WA represent the pressure of the wind on the sail. WA can be resolved into AB perpendicular to the sail, and BW parallel to it, the latter of which has no effect in pressing on the sail; therefore AB is the effective pressure on the sail. Were the vessel round, it would move in the direction BA. Let BA be resolved into CA and BC, the former, CA, acting in the direction of the keel or length of the vessel, or in the direction CA, and the latter perpendicular to it, or in the direction of the breadth. The former pressure, CA, is the only pressure that moves the vessel forward, the other, BC, makes it move sideways. From the form of the vessel, however, this latter force, BC, produces comparatively little lateral motion; any that it does occasion is called *leeway*.—By a similar double resolution, we may represent how much of the actual force of the wind is effective in turning round the arms of a wind-mill.

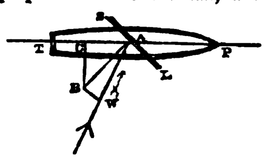


Fig. 9.

THIRD LAW.

When one stone is dashed against another stone at rest, the moving stone is hit as hard, and is as likely to break, as the one at rest; and when one person knocks his head against his neighbour's, it is difficult to say which is most hurt. The hand pressed against a fixed body is equally pressed in its turn. If a man standing in a boat attempt to push off another boat of the same size that is alongside, both boats will recede equally from each other; if he pull the other boat towards him, his own boat advances half-way to meet it. A magnet draws a piece of iron towards it; but the magnet is also drawn towards the iron, as is seen when they are both suspended so as to move freely. In all these cases, we see that the body that we consider as acting upon the other, is itself acted upon in turn, and in the opposite direction: this is what is meant by *reaction*.

In saying that the action and reaction are *equal*, it is meant that the momentum produced or destroyed on both sides is the same. If the magnet and the piece of iron above spoken of are of the same weight, they move to meet each other with equal velocities, for thus only can the momentum be the same in both cases. If the magnet is three times the weight of the piece of iron, the iron must move with three times the velocity of the magnet in order to have equal moving force; and so it is found to do. In the case of the boats, suppose the one in which the man is seated to be ten times the weight of the other, then for every ten feet that the light one moves off, the heavy one will recede one foot. The two will thus have the same momentum; and if each were to strike an object, an equal shock would be given in both cases.

In the last instance, both motions would still be visible. But let a boat of a ton weight be pushed away from the side of a ship of a thousand tons' weight, and then only one seems to move; for while the boat moves off a yard, the ship recedes only the thousandth part of a yard, which it would require minute observation and measurement to render apparent. From this we can pass to the extreme case of a boat pushed off from shore. Where is the evidence of reaction here? We see none, it is true; still, the consideration of the cases already adduced, and of a thousand similar, lead us irresistibly to believe that the shore, if it is free to move, must recede from the boat. But the shore can move only by carrying the earth with it; and considering the vast mass of the earth compared with that of the boat, the space moved over would defy measurement, even if we had any fixed mark to count from. We cannot help believing, then, that when a stone falls—in other words, when the earth draws a stone towards it—the earth is itself drawn, or falls, towards the stone.

COMMON MOTION.

When a system of bodies has, from any cause, received a common motion, their positions, with regard to one another, remain unaffected by it, and in considering their relative motions, we may leave their common motion out of account; everything is as if the system were at rest. This arises from the property of inertia, as already expounded. When a ship is going steadily, all things go on in the cabin as in a room. On deck, a ball thrown upwards comes down in the same spot; the deck has not slipped away from under it. The *motal inertia* of the ball carried it on while in the air with the motion it had acquired from the ship.

The feats of equestrians depend upon this law of common motion. Riding at full speed, they throw up balls, which return into the hand. The rider springs right up from the saddle, and alights on it again without falling behind the horse. When a bar is held in his way above the horse, he does not require to leap forward in surmounting it; he springs directly upwards, and this upward motion, combined with the forward motion he has in common with the horse, results in carrying him in a curve over the obstacle, and planting him on the very spot of the horse's back he sprung from.

All bodies, at any part of the earth's surface, have a common motion eastward along with the earth in its rotation. The velocity of that motion is greatest at the equator, and grows less towards the poles, as the circles described grow less and less. When a current of air, then, or of water in the ocean, is moving from any place in the northern hemisphere towards the equator, it carries the eastward velocity of the place it starts from to places where that velocity is greater; it thus has a tendency to fall behind the surface of the solid earth, which gives it the semblance of being deflected from its direct south course towards the west. (See METEOROLOGY.)

TERRESTRIAL GRAVITY.

It is a law, as we have seen, wide as the universe, that every particle of matter acts upon every other particle by the force known as gravitation, which draws them one towards another. We are now to consider the laws of this force, and explain the more important phenomena it gives rise to.

The attraction of gravitation is always in proportion to the mass of the attracting body. This will be readily admitted. A force is exerted by each atom, and the more atoms the more force. It is not the volume or bulk of the body, but its quantity of matter that decides its effect. Gravitation, again, acts at all distances, but with diminished effect as the distance increases. The decrease, however, does not go on in a simple proportion; twice the distance does not give simply half the attraction. If, at the distance of a foot, the force of attraction were a pound, at the distance of 2 feet, it would be $\frac{1}{4}$ of a pound; at 3 feet, $\frac{1}{9}$ of a pound; at 4 feet, $\frac{1}{16}$ of a pound. This is expressed by saying that attraction varies inversely as the squares of the distances between the bodies.

This law holds with many other influences besides gravitation; with light, for instance, and whatever is diffused from a centre in all directions. By considering fig. 12, we see that the same quantity of light which, at a yard from a candle, is diffused over a board of one foot square, is, at the distance of two yards,

diffused over a board having a side of two feet, but containing four squares of one foot to the side.

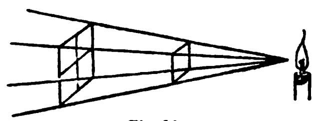


Fig. 10.

The distance between two mutually attracting globes is measured from centre to centre. The attraction of the earth, then, on a body at its surface is exerted at the distance of about 4000 miles, which is the length of its *semi-diameter;* at the height of 4000 miles above the surface, or at the distance of two semi-diameters from the centre, the attraction is reduced to one-fourth. The moon being at the distance of sixty semi-diameters, the earth draws it with a force which is only a 3600th part of what it would be, were the moon at the earth's surface. It belongs to astronomy to treat of gravitation as ruling the planetary motions; we have here to speak of the phenomena it produces on bodies at or near the earth's surface.

The attraction of the earth for bodies on its surface is so strong, owing to its overwhelming mass, that it overpowers their attraction for one another, and renders it in most cases inappreciable. But a plumb-line suspended near a large mountain is sensibly drawn from the perpendicular; and by a delicate instrument, called the torsion-balance, the action of a large ball upon a small one has been measured. The *weight* or gravity of a body is another name for the force with which it is drawn towards the earth.

The force of gravity is directed towards the earth's centre. A plumb-line indicates the direction, and we usually call it *downward;* but *down* and *up* are no fixed directions; they vary for every part of the earth's surface, and what is *down* to us, is *up* to our antipodes. This is shewn in the figure, which represents balls falling towards the earth at three different places on the surface. At points, however, not far distant from one another, downward or vertical lines do not differ sensibly from parallel lines, owing to the great distance of the centre.

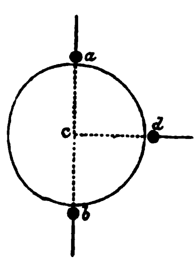


Fig. 11.

Falling Bodies.

Perhaps nothing explains more phenomena than the complete understanding of what takes place when a body falls; for half the motions in the world are caused, directly or indirectly, by falling. Falling is the best instance of a *uniformly accelerated* motion. Gravity not only puts a body in motion, but *continues* to act on it with equal force after it is in motion, and thus is uniformly adding to its speed. This acceleration is seen in every body dropped from a height through the air; and no less in a rock rolling down a declivity, which continually gathers force as it descends, till its momentum is sufficient to shatter itself and everything it encounters to pieces. In a water-fall, the increasing velocity breaks off the lower part of the descending column in drops, which separate more and more as they descend. When a viscid liquid, like molasses, is poured out from a height, the bulky sluggish stream becomes gradually rapid and smaller, and is at last reduced to a thread; but wherever a vessel is held into the stream, it fills equally fast.

All bodies, heavy and light, would fall equally fast, if the resistance of the air were removed. A ball of lead two pounds' weight does not fall faster than a ball of one pound. A gold leaf, however, will fall considerably slower than the same gold in a solid state, because it exposes much more surface to the air. That this is the cause of the difference, is shewn by an experiment with the air-pump, in which a guinea and a feather are dropped in a vacuum, and fall to the bottom together.

It has been well ascertained by observation, that when a body begins to fall from a state of rest, it descends 16 feet 1 inch in the first second of time. Suppose that no fall had ever been observed beyond that point, and that we had to find by reasoning what the body would do during the next second. The first consideration is, How far would the body fall, if gravity were to cease?—in other words, What velocity has it acquired? It would not be unnatural to say 16 feet (we omit the 1 inch), since that is the space it fell in the second that is ended; but reflection shews that this cannot be the case. During the first half of the second, it made very little way, and the greater part of the distance was passed over in the last half; 16 feet expresses the mean velocity, or the velocity it had at the middle of the second, and at the end it must have been moving with a velocity just double the mean. The velocity acquired, then, at the end of the first second is 32 feet; and if gravity were to cease, it would, by the law of inertia, move over 32 feet in the next second. But gravity still acting, will make it fall another 16 feet in addition to the 32, or 48 feet in all; and will create as much velocity in addition as it created in the first second, so that if it were to cease at the end of the second second, the body would move 64 feet in the third second. Thus, during the second second, the body will fall through three spaces of 16 feet, and at the end of it, will have its velocity double of what it was at the end of the first second. The whole space fallen during the two seconds will thus be four spaces of 16 feet.

We arrive at this result by reasoning, and observation proves it correct. Without giving the steps of the investigation for the succeeding spaces of time, the results may be exhibited in the following table:

Number of Seconds.	1	2	3	4	5	&c.
Velocities at the end of number of seconds, in spaces of 16 feet, .	2	4	6	8	10	&c.
Spaces fallen through during each successive second, ...	1	3	5	7	9	&c.
Spaces counted from beginning of fall, ...	1	4	9	16	25	&c.

For example: The third column, headed 3 (seconds), informs us that at the end of 3 seconds a falling body is moving (for the instant) at the rate of 6 spaces of 16 feet—that is, of 96 feet—a second; that during the third second it falls five spaces, or 80 feet; and that the whole distance fallen during all the three seconds is 9 spaces, or 144 feet.

The distances that bodies fall, then, do not increase simply as the times, but as the *squares* of the times. To find, therefore, how far a body will fall in any number of seconds, multiply the number of seconds by itself, and that product by 16. Thus, in 7 seconds, a body will fall $7 \times 7 \times 16 = 784$ feet. The height of a precipice might be roughly measured in this way, by observing how many seconds a stone takes to reach the bottom.

As a body in descending to the earth receives increasing accessions to its velocity during every successive second, so when a body is projected upwards from the surface of the earth, its velocity decreases in the same proportion till it comes to a state of momentary rest, when it instantly begins to descend with a gradually increasing velocity, which at any point in the descent is equal to its velocity at the same point when ascending. In this calculation, however, we omit the influence of the atmosphere.

Projectiles.

Any heavy body launched or *projected* into the air with an impulse, is a projectile; and to investigate the

motions of such bodies forms a distinct branch of the science of motion.

Suppose a cannon-ball fired from the top of a tower, whose height is represented by the line A4′, in the direction of the horizontal line AB. The force of the

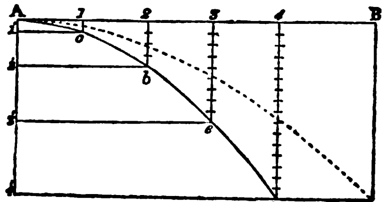


Fig. 12.

gunpowder ceases to act as the ball leaves the cannon, and the ball retains a uniform velocity which would carry it over equal spaces in equal times. Let A1 be the space the ball would describe in a second, if acted on only by the projectile force, and set off a number of equal spaces along AB. Now, from the moment the ball leaves the mouth of the cannon, it is acted on by gravity; and while moving in the direction of AB, also falls; so that at the end of a second it must be 16 feet lower than it would have been if gravity had not acted—that is, if we take the perpendicular line 1*c* to represent 16 feet, the ball will at the end of the first second be at *c*. The horizontal motion being uniform, the ball at the end of the second second would be at 2, or twice as far towards B; but its downward accelerated motion has in the meantime dragged it down through three spaces more—in all four spaces—of 16 feet below the horizontal line. Making 2*b*, therefore, equal to four times 1*c*, gives *b* as the point where the ball will be at the end of the second second. By similar reasoning, if 3*e* is made equal to nine times 1*c*, 4*f* equal to 16 times 1*c*, &c., according to the law of accelerated motion; *c*, *f*, &c., will be the points at which the ball will be found at the end of the third, fourth, &c., seconds. The resultant of these two dissimilar motions, the one uniform, and the other uniformly accelerated, is a curve of the kind called a parabola, as represented in the figure.

From the above investigation, this remarkable consequence follows: that a body projected horizontally from a height above a level plane, comes to the ground as soon as if it were let fall perpendicularly. The ball reaches *f* in the same time that it would fall from A to 4′. A greater velocity of projection would make it take a wider flight; but its horizontal motion does not interfere with its downward motion, and at the end of four seconds it must be at some point in the same horizontal

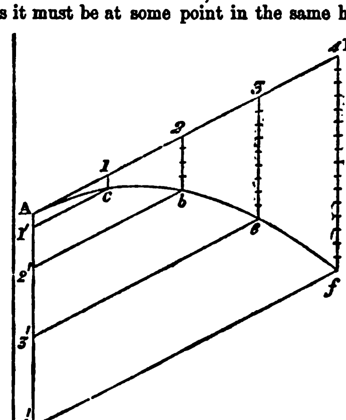


Fig. 13.

line—at *g*, for example. Two balls, then, projected horizontally from the same height above a level plane, though the one may range only a mile, and the other two miles, will reach the ground at the same time.

Projectiles are mostly thrown, not horizontally, but in an oblique direction. We arrive, however, at the path described in the same way as in the last case. AB, in fig. 13, is the line of projection as before, and 1, 2, 3, 4, are the points to which the velocity of the ball would carry it in 1, 2, 3, 4 seconds; while 1*c*, 2*b*, 3*e*, 4*f*, represent the distances which gravity will drag it downward from its original direction in the same times respectively. When the elevation of the direction and the velocity are given, Conic Sections teaches us how to find the distance and time of flight of a projectile, the direction of the ground being also supposed known.

The laws above arrived at respecting projectiles are strictly true, only on the supposition that the movements are made in empty space. But every projectile has to encounter the resistance of the air; and that resistance becomes so great when the velocity is very high, that in the practice of gunnery the theory is of little value. With a small velocity, however, a body thrown through the air describes a path not differing much from a parabola.

Since the distance of the flight, and the width of the curve described by a projectile, increase with its initial velocity, we can conceive the velocity increased until the curve became as large as that of the earth itself. If this were the case, the projectile, instead of falling, would, if the resistance of the air were removed, continue to go round and round the earth for ever. We thus arrive at the idea of planetary motion. The moon, for instance, is constantly falling towards the earth, like a cannon-ball shot horizontally; but the projectile velocity which it had from the beginning, and which, as it moves in empty space, it retains undiminished, is sufficient to carry it clear round in the curve called its orbit.

Centre of Gravity.

The centre of gravity of a body is that point about which the body balances itself in all positions. When a rod of uniform thickness and density is suspended by its middle point, it remains at rest. There is as much matter on the one side as the other; the atoms balance one another in pairs; and it is as if the whole were collected at the point of suspension. The centre of gravity of such a rod is the central point at its middle part; and if the substance of the rod is pierced, and this central point rested on a fine needle, the rod will remain immovable in whatever position it is put.

Whenever bodies are regularly shaped, and of uniform density, their centres of gravity may be found by mathematical measurement, as in the case of the rod. Thus the centre of gravity of a globe is evidently in its middle point, or centre of dimension. In whatever direction a plane is made to pass through the centre, it cuts the sphere into two equal parts, and every particle in the one half has an equal and corresponding particle in the other similarly situated, so as to balance it. Suspend the centre, therefore, and the globe remains at rest, whichever side is uppermost. Similarly, the centre of gravity of a block of wood, whether cubical or oblong, is in its middle point, which is easily found by measurement.

The position of the centre of gravity in a triangular-shaped body is not so obvious. It is thus found. If ABC represent the surface of a thin triangular board, we may suppose it composed of a number of small rods laid side by side, the line AB representing the first, and the others gradually diminishing in length to the top. Now, the centre of gravity of the rod AB is in its middle point D; and if we join the points D and C

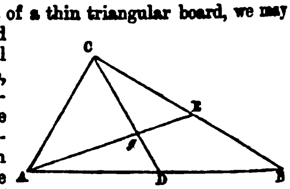


Fig. 14.

the line will pass through the centres of gravity of all the other rods; because it is a property of a line drawn from the top of a triangle to the middle of the opposite side, to bisect or pass through the middle of all lines in the triangle parallel to that side. The centre of gravity of the whole, therefore, must lie somewhere in the line CD. Again, by conceiving the triangle made up of rods parallel to the side CB, and drawing a line from A to the middle point E, we see that the centre of gravity must, in like manner, lie somewhere in the line AE. Now, since it lies also in CD, it can lie only where the two cross—namely, at *g*. We have thus found the centre of gravity of the surface, as it were; and if the board have any sensible thickness, its actual centre of gravity will lie behind *g*, at the distance of half the thickness. It is one of the properties of the triangle, that the line D*g*, determined as above, is always one-third of the whole line DC; thus the centre of gravity of a triangle is readily found.

When two balls are connected by an inflexible rod, they form but one body, and the common centre of gravity is not situated in either, but between them in the rod joining their centres. If the balls are equal in mass, it will evidently be in the middle of the rod; but if they are unequal, the point where they balance each other is found to lie nearer to the larger mass.

The centre of gravity has always a tendency to seek the lowest point, and this enables us readily to find the centre of gravity of an irregular body. For example, let a painter's pallet be suspended from the thumb-hole, as in the figure; we know that the centre of gravity must be perpendicularly below the point of suspension, and if we allow a plumb-line or a straight rod to hang down from that point in front of the pallet, and mark the line under it, the centre of gravity must be on that line. Next, suspend the pallet from any other point, D, and apply the plummet as before, and another line is found also containing the centre of gravity, which must therefore be where the lines cross. If a third line of direction is tried, it will be found to pass through the same point.

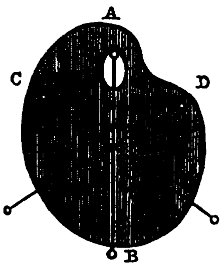


Fig. 15.

A perpendicular line from the centre of gravity, which is called the *line of direction*, must fall within the base of any object resting on the ground, otherwise it will fall. A structure may overhang its base within certain limits. In A (fig. 16) the line of direction falls within the base,

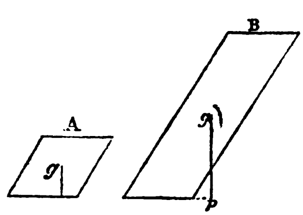


Fig. 16.

so that the centre is still supported, and would have to *rise* before the body could tumble; in B, the centre is unsupported, and moves in a descending curve from the first. The instability here arises from the *height* of the object, for the slope and base are the same in both.

This explains why vehicles when loaded high, or made *top-heavy*, are so easily upset. Figure 17 represents a cart crossing an inclined plane; or we may suppose that one wheel is tilted up in passing over a stone. With a load of stones, the centre of gravity would be about C, and the line of direction falling just under the wheel, the cart would escape being upset, though it might be narrowly. But if the load is such as to throw the centre of gravity into the position C′, the vehicle must fall over.

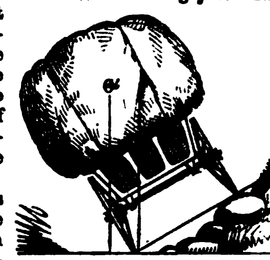


Fig. 17.

When a man stands on both legs, the centre of gravity falls between the feet; and the stability is increased by placing the feet apart. In resting on one foot, the body must be thrown over that foot; hence walking requires that the body be swayed slightly from side to side. In persons of a broad build, this oscillating motion is necessarily greater than in others, and hence the gait called a *waddle*. The walk of the duck is an extreme case of the same thing.

The Pendulum.

Any heavy body, such as a ball, suspended by a string or rod, so as to swing freely, constitutes a pendulum. Swinging is no less an effect of gravity than falling; and from the importance of the pendulum, as a measurer of time, the phenomenon deserves attentive study.

In the accompanying cut, a pendulum of the most common construction is represented. A is the axis or point of suspension; B is the rod; C is the *bob*, consisting of a ball, or a round flattish piece of metal, which is fastened to the rod by a screw behind, and by which screw it can be raised or lowered on the rod; DD′ is the path or arc which the ball traverses in swinging. When the ball is drawn to one side, as to D, gravity urges it downwards, while the tension of the rod draws it towards A. The composition of the two forces makes it describe a descending curve to C, where gravity is completely counteracted by the opposite pull of the rod. But the ball does not stop here; it goes on, by the law of inertia, in the ascending curve CD′, until gravity destroy its acquired motion. If friction and the resistance of the air did not interfere, the ball would reach the same elevation as it started from. But these causes gradually render the ascent less and less, and at last bring the pendulum, when it has no maintaining power, to a state of rest.

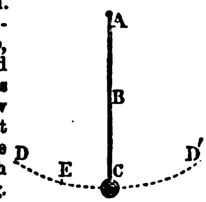


Fig. 18.

One sweep of a pendulum from D to D′ is called an *oscillation*. The size or *amplitude* of the oscillation is measured by the number of degrees in the arc, each degree being a 360th part of the whole circle. For reasons that will appear, pendulums are generally made to describe small arcs, not exceeding 5° or 6°.

The most remarkable property of the oscillations of the pendulum, and that on which its use as a regulator of movement depends, is that, whether long or short, they are all performed in very nearly the same time. If we observe the vibrations of any body set aswinging, we find that though the arc it describes is continually diminishing, there is no sensible shortening of the time in which the single sweeps are accomplished. As the journey becomes less, so does the velocity. Galileo is said to have been the first that distinctly noted and investigated this important fact. The cause is easily seen. The wider the sweep of the ball, the steeper is its descent at the beginning, which gives it a greater velocity, and enables it to go over the longer journey in the same time as over a shorter.

It is only short oscillations that are thus *isochronous*,

as it is called; when the arcs are large, the steepness does not increase in exact proportion to the length, and therefore the isochronism is not perfect. Accordingly, pendulums are made to swing in short arcs; and then, though no contrivance could make the extent of the oscillations exactly uniform, the times are virtually equal.

But though the time of oscillation is not affected by the largeness of the arc, it is by the length of the pendulum itself. Long pendulums vibrate more slowly than short ones. Though the balls B and D in the fig. have the same amplitude of vibration, or go over corresponding arcs, the journey of the one is longer than that of the other. But the steepness of descent, or inclination of the path, is the same in both; therefore B must take longer time to perform its journey than D. We must not, however, conclude that when the length of the arc, or, which is the same thing, of the pendulum, is doubled, the time of oscillation is also doubled. The motion of the pendulum is an accelerated motion; and, as in all other uniformly accelerated motions, the spaces described are as the squares of the times. To give double the time of vibration, then, requires the pendulum to be four times as long; treble the time, nine times as long; and so on.

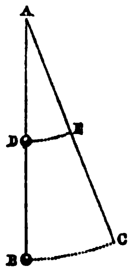


Fig. 19.

The truth of this is easily proved by experiment. Suspend three musket-balls on double threads, as in the figure, so that the lengths measured in the dotted line may be as 1, 4, and 9. While the lowest ball makes one oscillation, the highest will be found to make three, and the middle ball two.

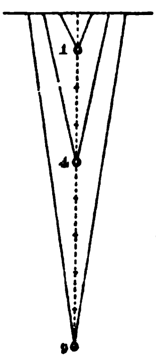


Fig. 20.

A pendulum of a little more than 39 inches beats seconds, and one of one-fourth that length beats half-seconds. As a pendulum that beats seconds must always be of the same length, it forms a fixed standard of measure which can be found again when artificial standards are lost.

When we say that the seconds' pendulum is always of the same length, we must be understood to speak of the same place. In different places, its length varies. At the equator, owing to the shape of the earth, we are thirteen miles further from the centre than at the poles; and therefore the seconds' pendulum must be somewhat shorter at the equator, and grow gradually longer as the latitude increases. The following are the lengths of the seconds' pendulum at a few stations, embracing a considerable range of latitude:—

Spitzbergen,	79° 49′ 58″ N. Lat.,	39·2146 inches.
Edinburgh,	55 58 40 ″	39·1554 ″
London,	51 31 08 ″	39·1390 ″
Jamaica,	17 56 07 ″	39·0350 ″
Sierra Leone,	8 29 28 ″	39·0195 ″

The length of a pendulum is measured from the point of suspension, not to the bottom, or even the centre of the ball, but to a point called the *centre of oscillation*, where the whole mass of the swinging body—rod and ball together—may be supposed concentrated.

We may find pretty nearly the centre of oscillation of a common pendulum, or of any pendulous body, by suspending in front of it, and from the same axis, a small ball of lead attached to a fine thread. This ball and thread form what is called a *simple* pendulum, because the weight of the thread may be reckoned as nothing, and the matter is as nearly as possible in one point. Both bodies are now made to swing, and the thread is lengthened or shortened till the two vibrate in exactly the same time; when they come to rest, the centre of the spot on the pendulous body covered by the ball is the centre of oscillation.

A pendulum alone, without wheel-work, would form a time-keeper, if we took the trouble to observe and count its vibrations, and if friction and the resistance of the air did not, after a time, bring its motion to an end. The use of the wheel-work in a clock is to answer these two ends—to count and record the swings of the pendulum, and to act as a *maintaining power*—that is, to supply to the pendulum fresh motion in place of what is constantly being destroyed. It is still the pendulum that measures the time. A contrivance for bringing the pendulum into connection with the wheel-work, is called an *escapement*, of which there are several varieties. (See Chronology and Horology.)

For adjusting the length of the pendulum, the ball is made to slide on the rod by means of a fine screw. A difference in length of the 1000th part of an inch causes an error of about a second a day. Since all substances are expanded by heat and contracted by cold, changes of temperature must affect the rate of clocks, making them go slower in summer than in winter. *Compensation* pendulums, accordingly, have been contrived, in which expansion in one part is made to counteract expansion in another part. To save space, time-pieces are often regulated by pendulums one-fourth the ordinary length, and therefore beating half-seconds. But a long pendulum, with a heavy bob or ball, is desirable where evenness of rate is the object. A pendulum beating two seconds keeps time much more accurately than one beating single seconds.

CENTRIFUGAL FORCE AND CIRCULAR MOTION.

Motion in a circle, or in any other curve, is something constrained. Free motion is naturally *straight*. This, we have seen, is involved in the idea of inertia. To make a body in motion deviate from the straight line, requires a fresh force in a different direction from the straight line in which it is moving; and if we see a body moving in a circle, which is a constant series of deviations from the straight line, we may conclude there is a constant force acting on it to produce the bending, in addition to the impulse or impulses that urge it onward. Accordingly, when we make a ball whirl round rapidly at the end of a cord, we feel the cord stretched with a sensible force; the ball is pulling outwards, and the hand is pulling inwards. These two opposite pulls must of course be exactly equal, for they are a case of action and reaction. The line of direction of both passes through the centre of the circle, and therefore they are called *central forces*. The outward pull of the ball is called the *centrifugal*, or centre-flying force; the inward pull of the hand, the *centripetal*, or centre-seeking force. The tension of the cord is the measure of both forces.

When a body, constrained to move in a circle, is released from the restraint, what is the result? Suppose the ball B retained by the cord AB, and moving in the direction CEG, &c.; if relieved from the restraint of the cord, it does not fly directly away from the centre, in the line AB prolonged. It has still its onward motion in the direction of the curve, and the only effect of the release from the centripetal force is, that that motion ceases to be bent, and goes on straight in the direction it had at the instant. Now, at any point in a circle, the direction of the curve is that of a straight line drawn through the point at right angles to the diameter. Such a straight line is called a *tangent;* and thus motion in a circle, when released from the constraining force, becomes motion in the tangent, or flies off at a tangent. At C, for instance, the

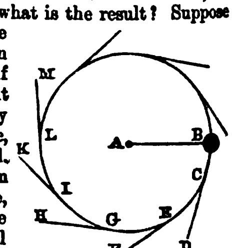


Fig. 21.

direction of the ball, when set free, would be CD; at I it would be IK.

The tendency to fly off from the centre and at a tangent, is exemplified in a multitude of phenomena. A stone let go from a sling is the most familiar instance. In grinding corn, it is the centrifugal tendency that makes the corn find its way from the centre, where it is admitted, gradually towards the circumference, where it escapes as meal. When a vessel with water in it is rapidly turned round like a horizontal wheel, the water recedes from the centre, and rises up round the sides. The potter takes advantage of this in his art: the soft clay is kept rapidly rotating while he is moulding it, and thus it tends of itself to widen out. The same is the case in glass-making, and many other arts.

In equestrian performances in a circus, both rider and horse incline their bodies inwards; they are leaning against a force which is impelling them outwards, and which thus sustains a part of their weight. A skater must do the same in describing a curve. Centrifugal force may be made altogether to counteract gravity: a tumbler of water placed in a sling may, by beginning with short swings, be at last made to go round and round in a vertical circle, where at one part the mouth is downward, without spilling a drop. If a round ball of soft clay be turned rapidly on a spindle, it ceases to be perfectly round in all directions: it bulges out at the middle and shortens in the direction of the spindle. This has happened to our earth; and to a still greater degree to Jupiter and Saturn, which have a more rapid rotation on their axes.

The centrifugal force of a body moving in a circle increases as the mass of the body, and as the square of the velocity. It is calculated that if the rotation of the earth were seventeen times faster than it is, centrifugal force at the equator would be equal to gravity; in other words, all bodies would be completely without weight, and a little increase of velocity would throw them off, to circle round like small satellites.

HEAT.

To account for the appearances presented by matter in its several forms of solid, liquid, and gas, we have seen it necessary (p. 196) to assume that there is a *repulsive* force at work among its molecules, counteracting and modifying the attractive forces. This repulsive force would seem to be identical with heat. Heat expands bodies; it overcomes the cohesion of their particles, converting solids into liquids, and liquids into gases; without it, there would be only one form of matter, the solid, and all life and motion would cease on the earth.

Perhaps no class of natural laws are more interesting in themselves, or more practically important, than the laws of heat. A knowledge of them is of direct application in every art and handicraft, as well as necessary for domestic economy and personal comfort. A full discussion of the subject would require a volume; it is only the most general facts that the limits of this treatise permit to be stated.

EXPANSION.

The greater number of bodies, whether solid, liquid, or gaseous, which are not decomposed by heat, are expanded by it: in other words, occupy a greater space when hot than when cold. Solids expand least, gases most, and liquids—speaking generally—are intermediate between them in expansibility.

To illustrate the expansion of solids, a rod of iron may be taken, and its length and diameter exactly measured at the temperature of the air. If it be now raised to a red heat, it will be found to have suffered an increase in length, and to be too wide to fit an aperture through which it passed before. When allowed to cool to its original temperature, it will exactly recover its previous dimensions.

The expansion of liquids is familiarly illustrated by heating a glass flask filled with any liquid. The liquid rapidly expands, and manifests its expansion by running over. If a bladder three-fourths filled with air is held near a fire, it becomes quite stretched, and may be made to burst, thus illustrating the expansion of gases.

Nearly every solid and liquid has an expansibility peculiar to itself. Among solids, the metals are the most expansible bodies. Zinc expands most, platinum probably least among bodies of the metallic class. Glass, brick, porcelain, marble, and stone, have small expansibilities. If a rod of iron which measures 819 lines in length when as cold as melting ice, is made as hot as boiling water, it is found to measure 820 lines. Between the freezing and boiling points, then, iron increases $\frac{1}{819}$ of its length; for the same increase of heat, glass expands only $\frac{1}{1147}$ of its length.

Among liquids, we find those which are most volatile more expansible than others. Thus spirit of wine is six times more expansible by heat than mercury. Gases, unlike solids and liquids, have not specific expansibilities, but each undergoes almost the same amount of expansion for the addition of the same amount of heat.

When heated from 32° to 212°, water dilates $\frac{1}{23}$ of its volume, mercury $\frac{1}{55}$, and alcohol $\frac{1}{9}$; air or any other gas about $\frac{1}{3}$. An increase of 1° of temperature, therefore, increases a body of air by $\frac{1}{480}$ of its bulk.

Water presents a singular irregularity in its expansions and contractions. If boiling water is taken, and allowed gradually to cool, it follows the general law, and goes on contracting until it is within a few degrees of freezing (at 39°); it then begins to dilate, and continues to do so till it come to 32°, the freezing-point. At the moment of becoming solid, it undergoes a sudden enlargement. It is this enlargement of freezing water that causes it to burst pipes and vessels in which it is confined; it is also the reason that ice is lighter than water, and floats on the surface. Ten cubic inches of ice weigh as much as nine cubic inches of water.

In laying the rails on a railway, and in all structures where metal is used, allowance must be made for the expansion and contraction of the metal by change of temperature. If iron rails were fastened down with their ends in close contact in a cold day, they would, when it became warm, press against one another, and become bent and twisted. Hence, a small space is left between the ends. The practical mechanic avails himself of the law of expansion in putting on the tires or rings of wagon-wheels and iron hoops on vats. Being made a degree too small at first, the tire or hoop is heated to redness, and in this state driven on; it is then cooled with water, when it contracts, and draws the parts of the wheel or vessel together with an irresistible force.

THE THERMOMETER.

The thermometer is an instrument in which *temperature*—that is, *the intensity of heat*—is measured by the amount of expansion it produces. The most convenient substances for the construction of thermometers are found to be mercury and alcohol, or spirit of wine. For ordinary temperatures, mercury is preferable; but when too much heat is withdrawn, it freezes or becomes solid, and therefore, for very low temperatures, alcohol is used, which cannot be congealed by any known cold. The mercury or alcohol is enclosed in a glass tube with a hollow bulb at one end, the other being closed. It is then graduated by first plunging it in melting ice, and marking on the glass, or on an ivory scale attached to it, the point at which the mercury comes to stand. This mark is the *freezing-point* of water, for water freezing and ice melting have the same temperature. The thermometer is next placed in boiling water, when the mercury rises to a certain height, and then continues steady. A second mark is here made, which is the *boiling-point*.

The space between these two points is then divided

into a number of equal parts, called *degrees*, and parts of the same length are set off above and below the boiling and freezing points, as far as required.

In the thermometer used in this country, the space between the freezing and boiling points is divided into 180 equal parts, and we begin counting at 32° below the freezing-point. A cipher is placed there, and it is called the zero or nothing-point of the thermometer. The freezing-point of water thus comes to be marked by the number 32°, and the boiling-point, which is 180° higher, by 212°. Thus, we say that a mixture of salt and snow reduces the thermometer to 0°, that the freezing-point of water is 32°, and that its boiling-point is 212°. In the thermometer chiefly used on the continent, the space between the freezing and boiling points of water is divided into 100 equal parts, and the graduation begins at the freezing-point, which is marked 0°, or zero. According to this thermometer, which is called the centigrade, water freezes at 0°, and boils at 100°.

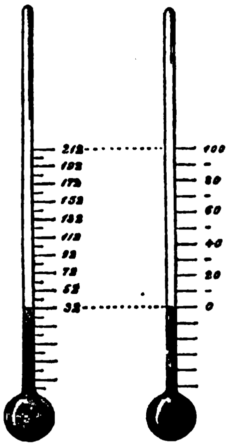


Fig. 22.

The centigrade thermometer is now much employed in scientific researches in this country. To prevent any confusion arising from its being mistaken for the thermometer first described, which is called, from its original maker—who was a Dutchman—Fahrenheit's, or the Fahrenheit thermometer, the letter F is placed after temperatures indicated by his thermometer, and the letter C after those denoted by the centigrade. Thus, water freezes at 32° F., or 0° C.; water boils at 212° F., or 100° C.

From its zero-point each thermometer counts downwards as well as upwards; and to distinguish the degrees below zero from those above it, the former are distinguished by prefixing to them the minus sign —. Thus, mercury is said to freeze at —40° F.; that is, at 40° below Fahrenheit's zero.

Another scale much used in Germany is that called Reaumur's, in which the freezing-point is marked 0°, and the boiling-point 80°. The degrees on this scale are thus larger than those of Fahrenheit, or even of the centigrade: 9° F. = 4° R., or 5° C.; and by means of these proportions, a temperature stated in one scale may be reduced to either of the others, care being taken to allow for Fahrenheit's scale commencing, not at the freezing-point, as the others do, but 32° below it.

Examples of converting degrees of one scale into those of another:

$$20^\circ \text{ C.} = \frac{20 \times 9}{5} + 32 = 68^\circ \text{ F.}$$

$$20^\circ \text{ R.} = \frac{20 \times 9}{4} + 32 = 77^\circ \text{ F.}$$

$$68^\circ \text{ F.} = \frac{(68 - 32) \times 5}{9} = 20^\circ \text{ C.}$$

$$77^\circ \text{ F.} = \frac{(77 - 32) \times 4}{9} = 20^\circ \text{ R.}$$

Fahrenheit chose the temperature of 32° below freezing as the zero-point of his scale, because it was the lowest that had then been observed, and was considered to indicate the complete absence of heat; but it is now known that there are natural temperatures at least 90° below this; and by artificial mixtures, a cold has been produced of —146° F. This last temperature is said to reduce alcohol to the consistency of melting wax, indicating that it is near its freezing-point.

SPECIFIC HEAT.

Different substances require different quantities of heat to raise them to the same temperature. This is expressed by saying that each possesses a *specific capacity* for heat, or, more shortly, a *specific heat*. The fact can be proved in a variety of ways. Thus, if we cause equal quantities of bodies which have all been raised to the same temperature, to melt ice, we shall find that a much greater weight of it will be melted by one body than by another. Thus, mercury at 212° will melt much less ice than an equal quantity of water at the same temperature will, for the mercury has much less heat to give out, so as to produce liquefaction, than the water has.

Specific heats are generally stated with reference to equal weights, rather than to equal measures, of bodies. Thus, a pound of water in rising to a given temperature, absorbs thirty times more heat than a pound of mercury in rising to the same temperature; so that the capacity of water for heat exceeds that of mercury thirty times; and if we call the specific heat of mercury 1, that of water will be 30.

The great specific heat of water has a most important relation to the welfare of the living creatures on the globe. The sea, and other great beds of water, which spread over so large a portion of the earth, cannot in the hot seasons of the year become rapidly raised in temperature; in the cold seasons of the year, on the other hand, they cool slowly, and, moreover, in cooling, evolve much heat, which equalises the temperature of the air as well as that of the land.

The specific heat of bodies is diminished by compressing them or making them more dense. By compressing a portion of air in a syringe, its capacity for heat may be so diminished that the quantity it previously contained, which only raised it to the ordinary temperature, is sufficient, after compression, to make it so hot as to set fire to a piece of amadou, or German tinder. On the other hand, when air is dilated by removing pressure from it, as in the receiver of an air-pump, or in the upper regions of the atmosphere, its capacity for heat is increased, and its temperature falls, the same amount of heat no longer sufficing to warm it to the same degree.

PROPAGATION OF HEAT.

Heat is transferred from one portion of matter to another in three different ways, which are termed conduction, convection, and radiation. *Conduction* implies the passage of heat from one particle of matter to another in physical contact with it. *Convection* is the conveying or carrying of heat by particles of matter raised in temperature, and set in motion. *Radiation* is the emission of heat by a body such, for example, as a mass of red-hot iron at rest, and not in physical contact with the substances to which it communicates heat. The name has reference to the supposition that the heat passes in radii, or rays, like those of sunlight, which can find their way even through a vacuum, and do not appear to require the assistance of ponderable matter to determine their transference.

Conduction.

Conduction is best seen in solids, and particularly in metals, which are the best conductors. A rod of iron placed with one extremity in the fire speedily becomes hot at the opposite extremity, owing to the conduction of heat from particle to particle along the rod. Dense bodies are generally the best conductors; light and porous ones the worst. Feathers, down, fur, flannel, and most of the fabrics used for winter dresses, owe their so-called warmth to their low-conducting power for heat. Their action is altogether negative, being limited to the prevention of the rapid escape of heat generated

by the living beings whose bodies they cover. Hence the best way to preserve ice, is to wrap it in flannel, or other so-called warm covering; for the same means that retard the escape of heat from the living body, retard the access of heat from the air and surrounding objects to the ice.

If the conducting power of gold is expressed by 100, that of copper is 90, of iron 37, of lead 18, of marble 2·3, of porcelain 1·2, of brick earth 1·1. Vessels of porcelain and glass are liable to crack when hot water is suddenly poured into them, because these substances conduct heat slowly, and thus the part first touched by the water becomes expanded, while the parts adjoining are yet cold and unexpanded.

Liquids and gases are very bad conductors of heat, although, from the rapidity with which they rise in temperature, when heat is applied to them, they appear to be among the best conductors.

Convection.

Liquids and gases rise in temperature chiefly in consequence of the convection, not the conduction of heat by their particles. If a spirit-lamp is applied to the top of a tube filled with water, as represented in fig. 23, the upper portion of the liquid is soon heated to boiling, while hours will elapse before even a slight degree of heat will reach any distance down the column. But if the lamp is applied at the bottom of the tube, the heat is soon felt at the top, and the whole liquid is made to boil in a few minutes.

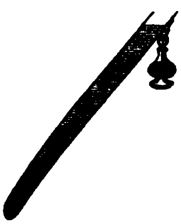


Fig. 23.

This remarkable difference is owing, not to any greater readiness that heat itself has to ascend than descend, for a rod of iron heats equally downwards and upwards, but to a motion that takes place among the particles of the liquid. If a pretty large glass flask be taken (fig. 24), and a few fragments of solid blue *litmus** dropped into it, after it has been filled nearly full of water, on applying heat by a small lamp to the bottom of the vessel, a central current of water, rendered distinctly visible by the blue colour it has acquired from the litmus, is seen to ascend till it reaches the surface of the liquid, when it bends over in every direction like the foliage of a palm-tree, and forms a number of descending currents. The currents which are thus occasioned by heating a liquid are determined by the fact, that when any portion of liquid is warmed, it expands, and has, in consequence, its specific gravity lessened.

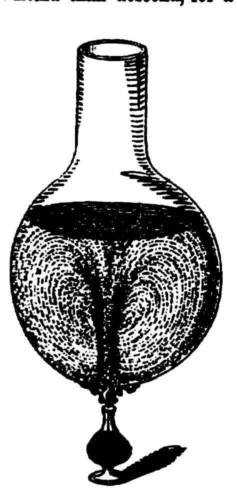


Fig. 24.

Air and other gases are raised in temperature in the same way that liquids are. They conduct heat with extreme slowness, as may be proved by applying heat to the top of an air-tight glass vessel with a thermometer suspended a little below the heated portion. But when the heat is applied from below, currents of circulation immediately begin, as in the case of a liquid. It is a popular belief that a large fire in the open air makes the wind rise; and so far it is quite true. The fire can only be maintained by constant lateral and descending streams of cold air to supply the place of the ascending column. When Moscow was burned, the wind rose so high, that men and horses could with difficulty keep their feet whilst passing through the burning streets.

Our sensations lead us into many errors regarding the temperature of bodies, which attention to their different conducting and conveying powers enables us to correct. Thus, of the several articles in the same room, the table feels colder than the cloth that covers it, and a marble slab colder than the table. They are, in fact, all of the same temperature—the temperature, namely, of the air in the room; but the marble being the best conductor, robs the hand most quickly of its heat.

The cooling effect of a liquid or fluid is much increased by motion, as when the hand is moved through cold water, thus bringing fresh unwarmed portions in contact with it in rapid succession. It is on this last principle that a degree of cold may be borne with a calm atmosphere, which becomes quite killing with even a moderate wind. When air is confined and prevented from circulating, it forms a non-conductor and a warm protection. Hence the effect of double-windows, and of plaster put on laths, so as to enclose a plate of air between it and the wall, instead of being laid on the wall itself. Woolly coverings and furs imprison the air within their substance, and prevent it from circulating, while they afford but few points of solid contact for the direct conduction of heat. These two circumstances combined, give them their remarkable power in arresting the escape of heat; and that power is greater the finer and lighter their texture. Swans' down is said to be the most perfect insulator of heat. From the same causes, snow is an excellent non-conductor, and, like a fleece of wool, protects the earth from any cold much below 32°.

Radiation.

Every hot body in the act of cooling, besides losing heat by the conductive and convective action of the solids and fluids in its neighbourhood, parts with much heat by radiation. Rays of heat pass away from the hot body till it has reached the temperature of the air or surrounding medium. In proof of this, it is only necessary to hang a hot body in the vacuum of the air-pump, when it rapidly cools, although it does not lose heat by either conduction or convection.

The rate of cooling of a hot solid body, so far as radiation is concerned, is remarkably influenced by the state of its surface, and in the case of liquids and gases by the state of the surface of the vessels containing them. Thus, hot water placed in a tin vessel coated externally with lampblack, cools twice as fast as it does in a bright tin vessel. Similarly, if two metallic vessels be taken, the one left bright, and the other covered with linen, hot water will be found to cool much faster in the covered than in the naked vessel. From these observations, it appears that a kettle covered with soot is much less suited for retaining water warm, than if it had a polished metallic surface. So, also, bright metallic covers are the best at table, and metallic tea-pots and coffee-pots are preferable to those of porcelain and stoneware.

Absorption and reflection of rays of heat.—Rays of heat follow almost the same laws as to reflection, absorption, refraction, &c., as rays of light (see OPTICS). When they fall on the surface of a body, they either enter it or are *reflected*. Those, again, that enter are either *transmitted*, like light through glass, or are retained and *absorbed*. It is only the rays that are absorbed that warm the body; those that are reflected off, as well as those that are transmitted, produce no effect on the temperature.

Surfaces that radiate heat best, are found also to imbibe it most readily. If a table, then, is formed of substances according to their power of radiating heat,

* A colouring-matter prepared from certain lichens, and readily procured from any druggist, or dealer in dye-stuffs.

the same table will serve for their power of absorption. The following is such a table, the radiating and absorbing power of a surface of lampblack being expressed by 100:

Lampblack,	100	Tin,	14
White-lead,	100	Brass, polished,	7
Writing-paper,	98	Copper,	7
Glass,	90	Gold,	3
Polished Iron,	23	Silver,	3
Mercury,	23		

Since all the rays not absorbed by a surface must be reflected, this table, read from the bottom upwards, will give the same surfaces in the order of their reflecting powers. It thus appears that the best protection for the head from the burning rays of the sun is a polished metal helmet.

All bodies, even the coldest, are constantly radiating off more or less heat, according to their temperature; all are therefore both giving and receiving rays; but the warmer give more than they receive, the colder receive more than they give. A surface presented towards the open sky, with nothing to radiate or throw back the rays it is emitting, soon becomes cold; but the slightest curtain, such as a net, hung up before it, sensibly arrests the dissipation of heat. It is in this way that clouds act as warm curtains to the earth, and often prevent frosts in spring and autumn nights. The different radiating powers of bodies explains why dew is sooner deposited on some substances than on others. Those that are good radiators lose their heat most quickly, and thus condense the vapour of the atmosphere.

Transmission of Thermal Rays.—Some substances, it has been observed, allow heat to pass through them, as light passes through glass; such substances are called *diathermanous*. Bodies are not diathermanous and transparent in the same degree; for black glass transmits heat well, and water, which is highly transparent, is the least diathermanous of liquids. Of solid bodies, rock-salt is the most diathermanous, alum the least so. Air is a highly diathermanous body. The heat of the sun, in radiating towards the earth, passes through the atmosphere without raising it in temperature, except to a very small extent. In consequence of this, the higher regions of the atmosphere, though nearer the sun, are much colder than the lower, which are raised in temperature by the transference to them of heat from the warm earth.

LATENT HEAT.

The word fluid includes two species—*liquid* fluids or liquids, and *elastic* fluids, or gases. Each of these conditions, liquidity and gaseity, is determined by a very remarkable addition of heat to the solid which it converts into a liquid, and to the liquid which it converts into a gas. The subject, therefore, divides itself into two sections—heat of liquidity, and heat of gaseity.

Heat of Liquidity.

When a solid body, such as ice, is watched whilst melting, a large quantity of heat is observed to enter it without raising its temperature in the slightest degree. This heat which enters the body serves only to melt or liquefy it, without rendering the liquid the least hotter than the solid was which yielded it. The water which flows from the melting ice is no warmer than the ice. The heat which thus renders a body liquid without warming it, is called *latent* or *insensible* heat, because it does not affect our sensations, and does not raise the thermometer. The fact of heat becoming latent, is most decisively demonstrated by mixing a certain quantity—say an ounce by weight—of ice, or still better, from its state of division, of snow at 32°, with an ounce of water at 172°. The result will be found to be, that the snow is all melted, and two ounces of water are procured at the temperature of 32°. The hot water in cooling from 172° to 32°, has lost 140° of heat, which changes the snow into water, but does not raise its temperature above that originally possessed by the snow.

What we have illustrated here with ice, holds good for all solids. Each one of them renders latent a certain quantity of heat in becoming liquid, and retains that heat so long as it remains liquid; when the liquid solidifies, it is again given up. Thus, when water freezes, the 140° of latent heat all abandon it, and manifest themselves as sensible heat. It is this necessity of absorbing such a quantity of heat, and getting rid of it again, that makes the processes of thawing and freezing go on so slowly. The heat developed in slaking lime, is the latent heat of fluidity becoming sensible. Water poured on burnt limestones does not *wet* them; it combines with them, and becomes a solid, and thus gives out its heat of fluidity.

Latent Heat of Gaseity—Vaporisation.

In boiling off a pound of water, or converting it into vapour, it can be shewn by experiment that as much heat is absorbed as would have raised its temperature about 1000°, if it had not gone off in steam. Yet the water rises no higher than 212°, however hot the fire is, and the steam is of the very same temperature as the water it rises from. Thus 1000° have disappeared or become latent in the steam; and before the steam can be condensed into water again, all this heat must be given out. (See STEAM-ENGINE.)

The same is true of the vapour that rises slowly and silently from water at temperatures below boiling (see METEOROLOGY). This absorption of latent heat is the cause of the cold which always accompanies evaporation. By placing water in a shallow vessel under the receiver of an air-pump, and withdrawing the vapour as fast as it rises, evaporation may be made to go on so rapidly that the water becomes frozen.

Sources of Heat.

Next to the sun (see ASTRONOMY), chemical combinations are the chief sources of heat. When two substances unite chemically, their temperature is almost always raised. When the heat is evolved so rapidly as to render the substances luminous—which most substances become when heated to a certain degree—the process is called *combustion* (see CHEMISTRY). *Fire* is a solid rendered luminous or incandescent by combustion; *flame* is gas at a white heat. In ordinary combustion one of the combining bodies is the oxygen of the atmosphere, which is called the *supporter* of combustion; the body with which the oxygen unites is the *combustible*. Most combustible substances are composed chiefly of two elements—carbon and hydrogen, for both of which oxygen has a strong affinity.

Animal heat has the same source as the heat of a fire or of a candle; it arises from a species of combustion. The oxygen taken into the body by the lungs, unites with the carbon and hydrogen of the waste parts of the blood and solids, and converts them into carbonic acid and vapour of water—burns them, in short, and thus produces heat. The average temperature of the human body is 98°·6; and it varies but little with race, climate, or state of health. The other mammalia have almost the same temperature as man; but that of birds is about 10° higher. The temperature of amphibia, fishes, &c., varies but little from the surrounding medium.

Heat can also be produced by mechanical means, such as compression, percussion, and friction. A piece of iron may be rendered hot by hammering; and axles of carriages often ignite from friction. It is found that the amount of heat thus produced is always in proportion to the force expended in the process.

MECHANICS—MACHINERY.

THE application of the laws of motion and forces to objects in nature, or contrivances in the arts, constitutes the branch of Natural Philosophy usually treated under the head MECHANICS, MECHANICAL POWERS, or ELEMENTS OF MACHINERY.

GENERAL DEFINITIONS.

The original signification of the word *machine*—which is the root of the various terms *mechanic*, *mechanical*, and so forth—was art, contrivance, ingenuity, or, in general, the means of bringing about an effect; hence a machine, in its widest acceptation, is an engine or instrument devised to produce an effect. The term *mechanical action* is applied to the action of forces that produce no change in the constitution of bodies, and is therefore distinguished from *chemical*, *vital*, or any other species of action. For example, the pounding of a piece of limestone to powder is strictly mechanical, whether it be effected by the blows of a hammer, or by the silent agency of running water; but the reduction of limestone to a similar state by sulphuric acid, is chemical. In the former case, all the elements of the original limestone remain in the powder; whereas in the latter, it is converted by the action of the acid into a very different compound.

In natural philosophy, machines are usually distinguished as *simple* or *complex*. A simple machine is equivalent to a tool or instrument, as a spade or lever; a complex machine is an engine in which different parts, or various tools, combine to produce the required effect. In ordinary language, these distinctions are not very minutely attended to, though indispensable to the precision of science. *Mechanics* is the term commonly employed to comprehend the science which treats of machines, whether theoretically of their powers, or practically of their application and construction.

Machines are, under all denominations or circumstances, only instruments through which power may be made to act. They only convey, regulate, or distribute the force or power which is communicated to them from some source of motion, and never create or generate power. But although a machine does not create power, or give more power than it has received, it practically applies the power which has been communicated to it in so convenient and easy a manner, that a result ensues almost as surprising as if it had actually generated the whole or a portion of the power it exhibits.

The main purpose in mechanical operations is to overcome, oppose, or sustain a certain resistance or force. This purpose is obtained by applying another species of force. According to the usual phraseology, the resistance or force to be overcome is termed the *weight*, and the force which is applied, the *power*.

The application of force by the human hands, without the aid of instruments or machines, is very limited. In almost all our operations of art, it is found necessary to call in the aid of instruments or machines of some kind. All the instruments which mankind have adopted for their use—from the piece of stick with which the savage scratches the ground as a plough, to the most elegantly finished piece of mechanism—act upon certain fixed principles in nature, which a long course of experience and scientific investigation has developed.

The mechanical powers which exhibit the working of these principles are strictly only three in number—namely, 1. The *Lever*; 2. The *Pulley*; and 3. The *Inclined Plane*. These may be called the Primary Mechanical Powers; and from two of them, the Lever and Inclined Plane, other three are formed, as follows:—1. *Wheel* and *Axle*, from the *Lever*; 2. *Wedge*, from the *Inclined Plane*; 3. *Screw*, from the *Inclined Plane*. These may be called the Secondary Mechanical Powers. The six altogether form the most usually occurring elements of complex machinery.

THE LEVER.

When a box, or other heavy body, is lifted in the hands, the power is applied to the weight directly; it acts without the intervention of machinery. But when a bar is used, as represented in the figure, resting on a support F, we have an instance of a machine interposed

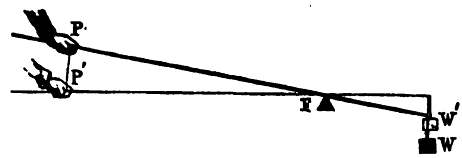


Fig. 1.

between the power and the weight. The effect of this machine is to modify the power in more ways than one. When the hand lifts the weight directly, it pulls upwards at the same point and with exactly the same force with which the weight pulls downwards. But with the machine the hand pushes or pulls downwards as well as the weight, and one effect of the solidity of the rod and of the fixed prop is to convert the downward force at P into an upward force at the other end. And not only this, but when the prop is nearer to the weight than to the power, the power seems to be increased; a downward pressure of one pound at P, causes an upward pull of, it may be, two or more pounds at W.

A rod or bar used in this way is called a *lever*, from the French word for 'to raise.' The point of support is called the *fulcrum*, and the distances from the fulcrum to the points of the lever where the *power* and the *weight* act, are called the *arms* of the lever. The lever is the most important of the simple machines, or mechanical powers, and, in its various modifications, enters most extensively into the composition of complex machinery. The law by which it acts, therefore, deserves attentive consideration. To comprehend thoroughly the nature of the *advantage* conferred by the lever, is to comprehend the fundamental principle of all mechanics.

In treating of the *theory* of the mechanical powers, certain assumptions are made. Thus the object of the lever is to *move* the weight; but the question really examined in the theory of the lever, is not what power is necessary to move a certain weight, but what power is necessary to balance it; what force at P will just keep W at rest, or suspended, if unsupported below. The subject is thus considered as belonging to Statics, or the doctrine of forces in equilibrium. It is obvious that when P and W once balance one another, the least additional force to P will suffice to begin motion. Again, it is assumed that machines are themselves without weight; that the rod or lever, for instance, is a mere rigid line. This is done for simplicity; in practice, the weight of the bar itself has an effect on the resistance, and must be allowed for. Another assumption is, that machines move without friction. A certain amount of force is always necessary to turn the lever about its axis or point of support; but this we do not take into the account. The amount of power consumed in overcoming friction, and the means of diminishing it, are questions for practical mechanics.

Law of the Lever.—When the fulcrum of a lever is placed as in the annexed figure, so that one of the arms, FA, is double the other, FB, it is found by experience that a weight of one pound at P will balance a weight of two pounds at W. And if the arms are in any other proportion—if, for example, AF were made seven feet long, while FB were only two feet; then two pounds at P would balance seven pounds at W. In general, *the power and the weight are to one another inversely as their distances from the fulcrum.*

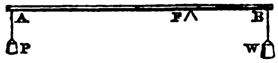


Fig. 2.

It looks at first sight like magic that a weight of one pound should be made equal in effect to one of two pounds. It seems as if the lever gave us the means of multiplying force to any amount; as if the strength of a boy might be put on a footing with that of a man. It is necessary to get over this false impression. There is no creation or multiplication of force in the lever, or in any other machine, as will appear from the following considerations. If we suppose the power slightly increased beyond what is necessary to balance the weight, it will begin to descend; but in descending six inches, for example, it will raise W only three inches, as represented in fig. 1. What is thus gained in one way, is lost in another; if we make a small force raise a great weight, the force must be exerted through a proportionally great space. One pound will lift ten pounds; but to lift the ten pounds through one foot it must descend ten feet. The two weights, when thus in motion, have equal momenta; the power multiplied into its velocity, is equal to the weight multiplied into its velocity. Since the velocities are in proportion to the distances from the centre of motion, this is the same as to say, the power multiplied into the length of its arm, is equal to the weight multiplied by its arm.

The comparative spaces through which P and W would move in the first instant of time if their equilibrium were disturbed, are called their *virtual* velocities; and the principle that when P and W balance each other, P multiplied by its virtual velocity is equal to W multiplied by its virtual velocity, is called the Golden Rule of Mechanics, and is true not only of the lever, but of all the other simple machines.

When the lever seems to multiply the power, it only accumulates or concentrates it. Suppose that a bale of goods of six hundredweights has to be raised to a platform a yard high, by a man who can lift only one hundredweight. If the bale can be taken to pieces, he may raise it by six lifts of a hundredweight each; but if it is impossible or inconvenient to divide it, he has recourse to a machine to accumulate his strength. By means of a lever with one arm six times the length of the other, he can raise the bale by a pull or a push of one hundredweight; but as the weight rises one yard, the long arm where the man's force acts must move over six yards. He thus makes six exertions of a yard each, exactly as if he lifted the bale in pieces; so that there is no actual saving of force. The lever acts like the milldam, that by treasuring up the flow of a small stream for twelve hours, gives it power to drive the wheel for one hour.

The above explanation of the principle of the lever rests on the notion of equal momenta and of the inertia of matter. The following demonstration is derived from the resolution of forces, and is more mathematical in its nature.

It may be assumed that equal weights, P and P′, suspended at equal arms, CA and CB, of a lever, must balance each other, for there is no reason why the rod should move in one direction more than in another. Also, if the two arms make an angle, as AC, CD, forming a bent lever, turning on the centre C, and if the equal weights, P and P″, both act still at right angles to their respective arms, there is no reason why the system should move; both forces have the same tendency to turn the system about the centre. Suppose such a bent lever, ACD, in

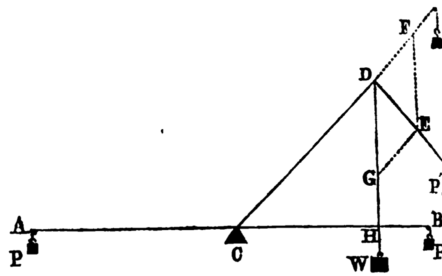


Fig. 3.

equilibrium (the weight P′ being removed), and then let the force P″ be decomposed into two other forces, thus: Prolong CD in the direction of F, draw DH perpendicular to AB, take the line DE to represent the amount of the force P″, and draw EG and EF parallel to CD and DH respectively. In this parallelogram (see Natural Philosophy), DF and DG represent two forces equivalent to the one force DE, and which may be substituted for it. But one of them, namely DF, has no tendency to turn the system round; it merely produces a pressure against the fixed centre, and may therefore be disregarded. There remains, therefore, the force DG (represented by the weight W), which has the same effect in turning the system round as P″ had. Moreover, when a force acts in the direction of any line, it is indifferent at what point of that line it is applied; the equilibrium of the system, therefore, will not be disturbed if the weight W, instead of being attached at D, be attached at H. Now, W being to P″ as the line DG to DE; and since the triangle GDE is similar to the triangle DCH, DG being to DE as DC to CH, it follows that W is to P″ or P, as DC to CH, or as AC to CH; that is, the weight is to the power as the arm of the power is to the arm of the weight. From this it follows, by the well-known property of proportion, that the weight multiplied by its distance from the fulcrum, is equal to the power multiplied by its distance.

This furnishes an easy rule for finding what force is necessary to move a given weight, with a given length of lever; or what weight a given force will move.

Example 1.—Suppose a log of wood, weighing a ton, or 2240 pounds, has to be raised by a lever whose arms are 20 feet and 3 feet respectively, what force must act on the longer arm? Here the product on the one side is $2240 \times 3 = 6720$; what number multiplied by 20 will produce the same product? This is found by dividing 6720 by 20. The quotient 336 is the number of pounds at the long arm, that will balance 2240 pounds at the short one.

Example 2.—A boy, using a pole as a lever, presses on the long arm, which is 15 feet, with a weight of 50 pounds; what weight will he be able to raise at the end of the short arm, which is 2 feet long? The product on the side of the power is 750; and 750 divided by 2 gives 375 pounds as the weight that can be raised.

Example 3.—Two boys, the one 80 pounds and the other 60 pounds' weight, are playing at see-saw with a beam 28 feet long; what point of the beam must rest on the support? The beam must evidently be divided by the fulcrum in proportion to the weights, that is as 80 to 60, or as 8 to 6; which is done thus: $8 + 6 : 8 : : 28 : \frac{28 \times 8}{14} = 16$ feet, the long arm. The short arm is therefore $28 - 16 = 12$. The products on both sides will be found equal; $16 \times 60 = 960$, and $12 \times 80 = 960$.

The power does not necessarily act at the long arm of the lever. The larger weight W (fig. 2) may be

used to raise the less P, as well as P to raise W. When the power acts at the short arm, it requires, of course, to be greater in amount than the resistance it has to overcome; but a small motion of the power in this case makes the weight move over a great space; what is lost in power is gained in velocity. This is often as great an object as an increase of power.

As yet we have represented the prop or fulcrum as situated between the power and the weight. This constitutes a *lever of the first kind*, as in fig. 4. But the power

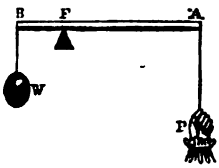


Fig. 4.

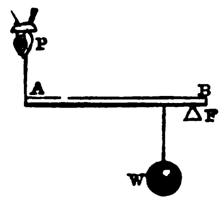


Fig. 5.

and weight may be both on the same side of the fulcrum. In this case, when the weight is between the power and fulcrum, as in fig. 5, the lever is *of the second kind;* and when the power is between the weight and fulcrum, as in fig. 6, it is a lever *of the third kind.*

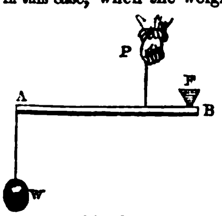


Fig. 6.

These different arrangements make no alteration in the principles already laid down. The effect of each of the forces, P and W, is still measured by its distance from the fulcrum. This distance forms its *leverage* or advantage; and the greater the leverage of either force, so much less does it require to be to balance the other.

The following are examples of implements which act, more or less, on the principle of the lever, beginning with the lever of the first kind.

When the common spade is used in delving, the blade is first forced into the soil by the foot, the handle is then pressed back, the edge of the undelved ground becomes a fulcrum, and the lever-power of the long handle enables a moderate pressure to dislodge the earth from its place. Fig. 7 represents an equally familiar example—namely,

Fig. 7.

a wood-sawyer or carpenter moving a log of timber from its place, by means of a long pole or beam of wood. Stone-masons use a lever of iron of this description, called a crow-bar.

The power of the first kind of lever is frequently seen to operate in machines or instruments having two arms. The most common examples of this nature are pincers, scissors, and similar instruments.

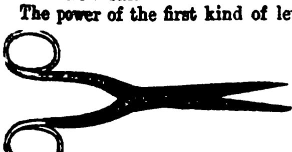


Fig. 8.

In the pair of scissors here represented, the two limbs are seen to be joined together by a rivet at the centre, which becomes the fulcrum of both.

A common scale-beam for weighing is an example of the first kind of lever, formed with two arms of equal length.

There is another kind of balance, called a *steelyard*, which consists of a lever with arms of unequal length, and acts upon the principle of distance from the fulcrum on the long arm compensating for weight on the short arm, as already defined. Fig. 9 is a representation of the steelyard balance. C is the fulcrum or pivot on which the beam is suspended, and freely plays as on an axis; A is the short arm, and the opposite end is the long arm; W is the scale for the reception of the article to be weighed. On the long arm a number of divisions are set off, marked 1, 2, 3, &c.; C1 being equal to CA, C2 equal to twice CA, &c. P is a weight of a certain

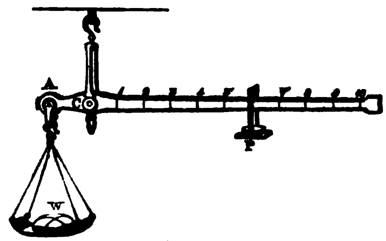


Fig. 9.

heaviness, and being movable by a ring, it can be slipped along the bar to any required point. The same weight is always used, which constitutes one of the principal conveniences of this kind of balance. In proportion as the article to be weighed in the scale W is heavy, so is the weight P slipped along to a greater distance from the fulcrum; and when it is brought to a point where it balances the article, the figure on the bar at that point indicates the amount of the weight. If P be one pound, and if, when suspended from the division at 6, it balance the weight at W, it is evident that the weight will be six times P, or six pounds. And so on with all the other divisions.

The steelyard, though not so ancient as the common balance, is of considerable antiquity. It was used by the Romans, and has long been in use among the Chinese. Neither the common balance nor the steelyard is suitable for shewing the varying weight or heaviness of an article at different latitudes of the earth's surface, because the weights employed are equally affected by the attraction of gravitation and centrifugal force, as the article to be weighed. For this purpose a balance formed of a spring of elastic metal is used.

Examples of the second kind of lever-power are also common. One of the most familiar is that of a man pushing or lifting forward a bale of goods, as represented in fig. 10, in which the bale or weight W presses against the lever between the power P and the fulcrum F.

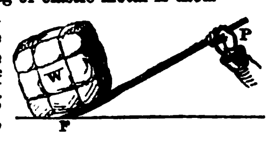


Fig. 10.

Another example of this lever is that of a man using a wheel-barrow, as represented in fig. 11. The axle of the wheel is the fulcrum; the body of the barrow, with its load, is the weight; and the two handles form the lever, the man's muscular strength being the power, and acting at the extremity, while the weight is situated between the extremity and the fulcrum. In proportion as the man shortens or lengthens the handles

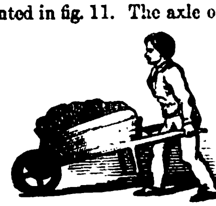


Fig. 11.

in holding them, so does he increase or diminish the weight he has to sustain; increasing or diminishing, however, by another law, the difficulty of pushing forward the barrow, according to the weight on the fulcrum.

Two men carrying a load between them on a pole is also an example of the second kind of lever. The load may either rest upon, or be dependent from, the pole. In the case of two porters carrying a sedan-chair by means of two poles, the load or weight is partly above and partly below the line of the lever. In the case of porters carrying a barrel slung from a pole, as in fig. 12, the weight is altogether below the lever. In both instances, the principle is the same. Each man acts as the power in lifting the weight, and at the same time each man becomes a fulcrum in respect to the other. If the weight hang fairly from the centre of the pole, each man will bear just a half of the burden; but if the weight be slipped along, to be nearer one end of the lever than the other, then the man who bears the shorter end of the pole supports a greater load than the man who is at the long end. The weight increases precisely in proportion as it advances towards him. Sometimes, when a man and a boy are carrying a hand-barrow between them, the man, in order to ease the weight as much as possible to the boy, holds by the arms of the barrow near to where they join the loaded part. In yoking horses to the extremities of cross-bars in ploughs, coaches, or other vehicles, if the cross-bar is not attached to the load by its middle point, one horse will have to pull more than the other.


Fig. 12.

An inflexible beam, resting on supports or fulcra at its two extremities, acts similarly to a lever of the second kind. Should no weight be appended to its centre, the weight of the material itself, when the extension is considerable, will be enough to bend it down, and even to break it. Extended flexible cords or chains are from this cause always bent down in the middle, no power of extension being able to overcome the gravity of the materials, acting at such an advantage of lever power.

The instrument used for cracking nuts (fig. 13) is an example of the second kind of lever with two arms or limbs. The fulcrum is the joint which connects the two limbs; the nut between them is the weight or resistance; and the hand which presses the limbs together, in order to break the nut, is the power. As each limb is a lever, a double lever-action takes place in the operation. The oar of a boat in rowing is also a lever of this kind. The hands of the sailor who pulls, constitute the power; the boat is the weight to be moved; and the water against which the blade of the oar pushes, the fulcrum.


Fig. 13.

In a lever of the third kind, the power must, from its position, be always greater than the weight; and from this circumstance it has sometimes been called the *losing* lever. But this gives a wrong impression; for what is lost in the amount of the power is gained in the velocity, or in the space over which the resisting weight is made to move. Levers of this kind are used where the object is not to gain power and overcome great resistance, but to produce rapid motion where the resistance is comparatively small.

An example is found in the footboard of the turning-lathe (fig. 14). The foot of the workman presses on the board or plank near the end which rests on the ground, or fulcrum, and, at the cost of a short movement of its own, causes the opposite extremity of the board to move in a downward direction over a considerable space.

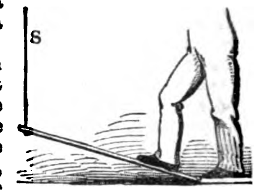


Fig. 14.

When earth is lifted on a spade, if the hand at the extremity of the handle is held fixed while the other makes the spade turn upon it as a centre, we have a lever of the third kind. If the hand that grasps the handle at some distance from the end is held fixed, and the other communicates the motion, it is a lever of the first kind. In practice, both hands move, acting reciprocally as power and fulcrum to each other. In using a pitchfork, a pencil, a pen, &c., the first and third levers are similarly combined.

The movements in the limbs of animals are mostly produced by the action of levers of the third kind. The tendons or ropes which move the bones are attached near the joints, which are the pivots or fulcra of the bone-levers. A striking instance is exhibited in the human arm. A strong muscle, arising in the shoulder, passes down in front over the joint of the elbow, and is inserted into one of the two parallel bones which compose the framework of the forearm, or from the elbow to the wrist. On being contracted in the slightest degree, at the impulse of the will, this muscle (the *power*) elevates instantaneously the hand (the *weight* or resistance) to the shoulder, bending the arm upon the elbow-joint (the *fulcrum*). Fig. 15 illustrates perfectly this mechanism of the arm. F represents the elbow-joint; P the power or will acting over, or from, the shoulder S, through the contracting muscle M; and B the arm from the hand to the elbow; while the weight W is an object supposed to be placed in the hand.

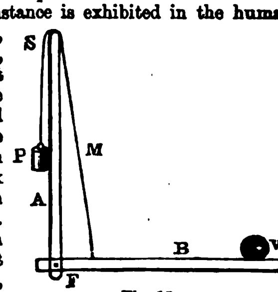


Fig. 15.

Nothing can better illustrate the characteristic advantages of levers of the third kind than this action in the human arm. The contraction of the muscle, to the extent of only one inch, raises the hand, even with a very considerable weight in it, through a semicircle of twenty-one inches; and by relaxing the muscle only a little, the hand, as represented in fig. 16, is allowed to drop over a similarly wide range. No doubt other muscles in the arm assist in this action, but the principal part is performed by the one described, and here indicated by the letter M.

It is worthy of observation, that in the second of these figures, illustrating the mechanism of the arm, the lever-power acts under increased disadvantage, from the greater inclination of the limb than in the preceding figure. We can raise or sustain a much larger weight with the hand when the arm is bent at right angles, than when it is extended nearly in a straight line; and the more the arm is stretched out, the more is the power diminished. What is gained, however, in force, is necessarily lost in extent of motion.

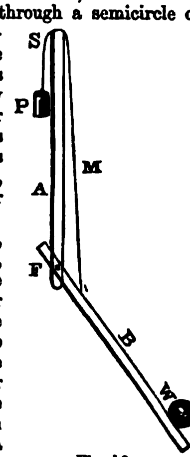


Fig. 16.

Compound Levers.

When several levers of the simple kinds are connected together, and are made to operate one upon the other, the machine so formed is called a *compound lever*. In this machine, as each lever acts with a power equal to the pressure on it of the next lever between it and the power, the force is increased or diminished according to the number or kind of levers employed. Fig. 17 represents a compound lever, consisting of three simple levers of the first kind, placed in a line, and each working on its own fulcrum. The same principle applies, in

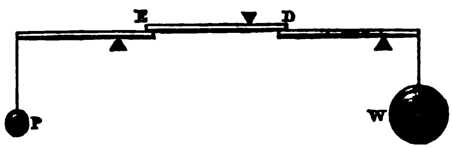


Fig. 17.

calculating the action of this combined lever, which holds for the simple lever.

It is supposed that the three levers in the figure are of the same length, the long arms being six inches each, and the short ones two inches each; required—the weight which a moving power of 1 pound at P will balance at W. In the first place, 1 pound at P would balance 3 pounds at E, according to the rule of calculation for the simple lever; for $1 \times 6 = 3 \times 2$. This upward pressure of 3 pounds at E, is next converted, by the second lever, into a downward pressure at D three times as great, or equal to 9 pounds; and, lastly, the downward pressure of 9 pounds at D is converted, by the third lever, into an upward pull at W of 3 times 9, or 27 pounds. Thus, 1 pound at P will balance 27 pounds at W; or, 1 ounce at P will balance 27 ounces at W—the proportions being always alike, whatever denomination of weight we employ.

In this instance, the increase of power is comparatively small, because the proportion between the long and short arms is only as 2 to 6, or 1 to 3. If we make the proportions more dissimilar, as 1 to 10, or 1 to 20, the increase of force becomes very great. For example, let the long arms be 18 inches each, and the short ones 1 inch each, and 1 pound at P will balance 18 pounds at E, and the second lever would be pushed up with a power of 18 pounds. This 18 being multiplied by 18, the length of the second lever, gives 324 pounds as the power which would press down the third lever. Lastly, multiply this 324 by the length of the third lever, 18, and the product is 5832 pounds, which would be the final weight at W, which 1 pound at P would raise.

The following is a general rule for calculating the advantages of a compound lever consisting of any number of levers, whether equal or not:—Call the arms of the different levers next the power the *arms of power*, and the other arms the *arms of weight;* then, if the lengths of the arms of power and the power itself be multiplied together, the product will be equal to the continued product of the arms of weight and the weight, when the power and weight are in equilibrium.

A similar result to that of a combination of levers might be produced by only one lever, provided it were long enough; but the operation would be both clumsy and inconvenient. By combining levers, and making them act one upon another, great weights may be balanced within a small compass, and with an exceedingly small power. On this account, machines are constructed with combinations of levers for weighing loaded carts and other heavy burdens. The cart is wheeled upon a sort of table placed level with the ground, beneath which the levers are arranged; and a small weight placed on a scale attached to the extreme point of the first lever balances the load, which rests on the table above the last lever. This species of weighing-machine is often to be seen at toll-bars.

Bent Levers.

In the foregoing examples of lever-power, the levers or bars are supposed to be straight, and the powers and weights, or forces, are supposed to act at right angles with them. But levers are frequently *bent* in their form, for purposes of convenience, and the powers and weights often act *obliquely*, or not at right angles.

In calculating the mechanical advantage, the chief matter for consideration is *obliquity* in the direction of the applied power and weight. Obliquity in the action of the forces generally diminishes the mechanical advantage. Whatever be the form of the lever, or the direction of the power and the weight, the mechanical advantage of the power or the weight is always represented by *a line drawn from the fulcrum, at right angles to the direction in which the forces are respectively exerted.*

Fig. 18 is a bent lever, with the power P hanging from A, and the weight W hanging from B. In this case, both the power and the weight act at right angles to an ideal line, drawn as from E to G across the fulcrum, which strikes the lines of direction of the forces at right angles. This ideal line therefore represents the true lever of calculation, and we proceed with it according to the ordinary rule for calculating lever-powers. In this manner the bending goes for nothing.

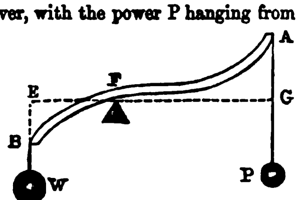


Fig. 18.

Fig. 19 is a straight lever with the power P acting obliquely from D to A, and the weight W acting obliquely from G to B. In order to calculate the power of this kind of lever, we must draw lines as represented in fig. 20. First, we draw a line obliquely upwards in the direction of the pulling-power. This line is seen dotted from A to M. We then draw a line off from it, or *at right angles* with it, to F, the fulcrum. This line is seen dotted, and marked H. We next draw a line obliquely upwards in the direction of the pull of the weight, as from B to N; and in the same manner as before draw a line *at right angles* from it. This line is seen dotted, and marked K. We have now found an ideal lever, with two arms, H and K. This ideal lever is the true lever of calculation, and we proceed with it according to the ordinary rule for calculating lever-powers.

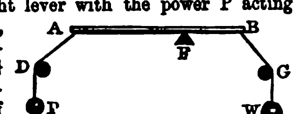


Fig. 19.

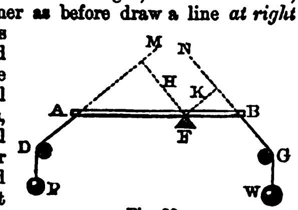


Fig. 20.

Sometimes the lever is bent in such a manner that the long arm rises perpendicularly from the fulcrum, as in fig. 21. In this case the upright long arm from F to A acts precisely as if it were horizontal, because the power or hand is supposed to act at right angles to the arm. If we were to draw an ideal line from the top of the arm at A directly downwards to F, it would descend straight through the arm, and hence in this case there would be no use in drawing it. The calculation may be made with the arm itself.

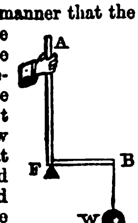


Fig. 21.

But if the power be made to draw obliquely downward, or not at right angles to the line from the fulcrum, we must draw an ideal line, as represented in fig. 22. The line of direction of the power is seen proceeding obliquely from A to the hand P. A dotted line H is drawn at right angles from this line to F, the fulcrum; the line H therefore represents the true arm of power of the lever.

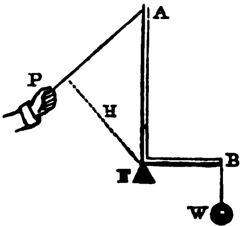


Fig. 22.

A pronged hammer employed to extract a nail, is an example of a bent lever, resembling those just mentioned.

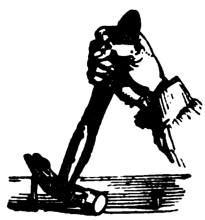


Fig. 23.

From the examples now given, it will be observed that, whatever be the shape or bending of the lever, and whatever the degree of obliquity of the applied force, the power of the machine may be calculated by drawing ideal lines at right angles from the lines of the forces to the fulcrum, and making the calculations from them.

THE WHEEL AND AXLE.

When a lever is movable upon an axis, and is susceptible of being turned completely round, it assumes the character of the diameter of a wheel. AB (fig. 24) is an equal-armed lever, fixed on an axis F. A force acting at A or B, if not held in equilibrium, would continue to turn the lever round and round.

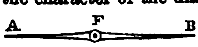


Fig. 24.

Let another lever CD (fig. 25), with arms of the same length, cross AB, turning on the same axis and fixed to AB, so as to form a solid system; it will be indifferent whether a force act at A, C, B, or D; it will have the same effect in turning the system on the common axis. The same is true of any number of levers crossing one another; and if a ring is made to unite their ends, like a wheel, a force acting at any point on the ring, will have the same effect as if it acted at the end of one of the levers. A wheel is thus a system of equal-armed levers crossing one another in the centre.

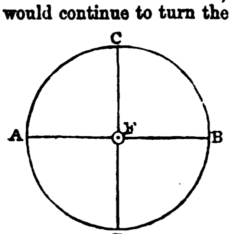


Fig. 25.

The way in which such a system is turned to account as a moving power is represented in fig. 26. A wheel is fixed on an axle, the ends of which turn in upright supports. A cord is wound round the wheel, and another round the axis in the opposite direction. If a weight, P, is then attached to the cord of the wheel, it will by its descent turn the wheel, and the axle with it; and the winding of the cord on the axle will lift the weight W attached to it. This is the machine called the *wheel and axle*, which may be characterised as a *perpetual lever*.

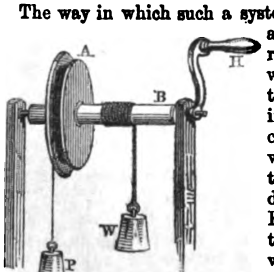


Fig. 26.

Fig. 27, presenting a section of the wheel and axle, shews the lever-power, with which the two forces act. F, the centre of both wheel and axle, is the fulcrum; AF, half the diameter of the wheel, is the distance from the fulcrum or arm, at which P acts; and FB, half the diameter of the axle, is the arm at which W acts. Thus, the larger the wheel, and the smaller the axle, the greater advantage the power has over the weight. But this advantage in power is gained at the sacrifice of speed, for every turn of a small axle raises the weight but a short way.

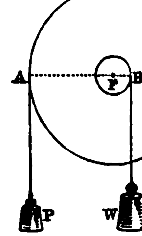


Fig. 27.

Instead of a wheel and weight, the axle may be turned by a handle H (fig. 26). The handle is just part of a wheel, and the force of the hand that turns it acts at an advantage proportioned to the wideness of the circuit it makes.

The proportion of the power to the weight in the wheel and axle is calculated precisely as in the case of the simple lever. If the diameter of the wheel is six times that of the axle, or, which is the same thing, if the circumference of the wheel is six times that of the axle, a power of one pound will raise a load of six pounds.

The principle of the wheel and axle, or perpetual lever, is introduced into various mechanical contrivances, which are of great use in many of the ordinary occupations of life. One of the simplest machines constructed on this principle is the common windlass for drawing water by a rope and bucket from wells. Coal is lifted from the pits in which it is dug by a similar contrivance, wrought by horse or steam power.

The capstan in general use on board of ships for hauling or drawing up anchors, and for other operations, is an example of the wheel and axle, constructed in an upright or vertical, instead of a horizontal, position. In fig. 28, one of these capstans is represented. The axle is placed upright, with the rope winding about it, and having a head pierced with holes for spokes or levers, which the men push against to cause the axle to turn. This is a powerful and convenient machine on shipboard; when not in use, the spokes are taken out and laid aside.

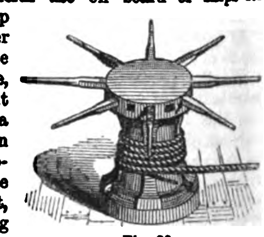


Fig. 28.

PULLEYS.

The pulley consists of a small wheel, called a *sheave*, turning on an axis in a block, with a flexible cord resting in a groove in the circumference of the wheel. There are two kinds of pulleys—the *fixed* and the *movable*.

The annexed cut represents a pulley, A, fixed by its block or frame to a beam or roof, B, and having two weights attached to the ends of the cord. In order that P and W may be in equilibrium in this case, it is evident that they must be equal. This appears from the wheel being a lever with equal arms, so that neither P nor W has any advantage. It is also plain that the cord, being free to move either way, must be equally stretched, or have the same *tension* throughout its whole length. A fixed pulley does not increase the power; it only serves to change the direction in which the power acts. This is often as great a gain as increase of power would be. A force, for instance, at P, pulling downwards, can raise W upwards.

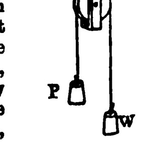


Fig. 29.

The same object might be gained by bending the cord

over a fixed bar, and making it slide on it; but in this case the friction of the cord on the surface of the bar would cause great resistance, and would chafe the cord; and to obviate this is the use of the sheave. Theoretically, then, the whole virtue of the pulley resides in the flexible cord.

The movable pulley is generally attached to the weight or resistance, and moves along with it. In the annexed cut, a cord is carried from a fixed point at A round a pulley B, from which the weight is suspended; it is then made to pass over a fixed pulley at C, and the power is represented by a hand drawing downwards. The parts of the cord BA and BC being equally stretched, each sustains evidently *half* the weight; but the part of the cord PC has the same tension as the rest, therefore P pulls down with a force equal to half the weight. A single movable pulley, then, *doubles* the effect of the power. The only effect of the fixed pulley C is to change the direction; if the hand were at C pulling upwards, it would sustain just half the weight.

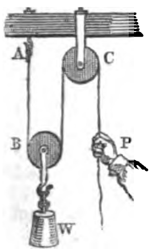


Fig. 30.

In order to save expenditure of power in lifting weights by pulleys, it is always contrived to cause some inanimate object—as, for instance, a beam or roof—to take a share of the weight, leaving only a portion to be borne by the person who pulls. But in this, as in all cases of mechanical advantage, the saving of power is effected only by a certain loss of time, or a longer continuation of labour. To lift a weight one foot from the ground by the movable pulley, a man must pull up the cord two feet.

As represented in fig. 31, a man may seat himself in a loop or seat attached to one end of a cord, and passing the cord over a fixed pulley above, may pull himself upwards by drawing at the other end of the cord. He requires to support with his arms only a little more than half the weight of his body in order to make the seat ascend. By adding a movable pulley and another fixed pulley to the apparatus, the exertion of pulling would be diminished one-half. An apparatus of this nature, having two fixed pulleys and one movable pulley, is used by masons and other artisans in making repairs on the fronts of buildings.


Fig. 31.

In all cases in which cords are drawn tightly, so as to hold objects in close contact, the same species of power or mechanical advantage is exemplified. For instance, in drawing a cord in lacing, or a thread in sewing, this distribution of strain is observable. If all the force of tension which is distributed throughout the sewing of a single pair of strong shoes were released and concentrated in one main draught, it would in all likelihood be a power sufficient to lift one or two tons in weight.

Technically, the wheel of a pulley is called a *sheave;* for protection and convenience, this sheave is ordinarily fixed with pivots in a mass of wood called a *block;* and the ropes or cords are called a *tackle.* The whole machine, fully mounted for working, is termed a *block and tackle.* By causing a wheel and axle to wind up the cord of a block and tackle, the power of the lever is combined with that of the pulley in the operation.

The power of pulleys is increased by a combination of wheels or sheaves in one tackle. There are different kinds of combinations or systems of pulleys. In some there is only one fixed pulley, and in others there are several. The following are examples of different combinations of pulleys:—

Fig. 32 represents a compound system of pulleys, by which the weight is distributed through four folds of the same cord, so as to leave only a fourth of the weight, whatever it may be, to be raised by the operator. In this illustration, the cord number 1 bears one-fourth of the weight; the cord number 2 bears a second fourth; the cord number 3 bears a third fourth; and the cord number 4 bears a fourth fourth. Here the mechanical advantage ceases. For although the cord number 4 passes over the topmost fixed pulley down to the hand of the operator, no more distribution of power takes place; this topmost pulley being of use only to change the direction of the power. The person who pulls has thus only a quarter of the weight to draw. If the weight be 100 pounds, he has the labour of pulling only 25 pounds. If there were 3 pulleys in the lower block, the power would be $\frac{1}{6}$ of the weight; if 4 pulleys, $\frac{1}{8}$; and so on; but every such addition causes more time to be spent in the operation, there being at every additional fold of the cord more cord to draw out, and also more friction to overcome.

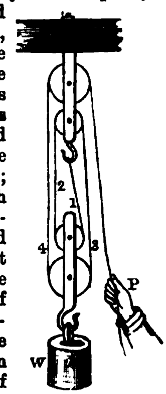


Fig. 32.

In the annexed system of pulleys (fig. 33), a series of movable pulleys, with different cords, are made to act successively on one another, and the effect is doubled by each pulley. At the extremity of the first cord, a power of one pound depends. This cord, marked 1, by being drawn below a movable pulley, supports two pounds—that is, 1 pound on each side. The next cord, marked 2, in the same manner supports four pounds, or 2 pounds on each side. The next cord, marked 4, supports eight pounds, or 4 pounds on each side. Thus, 1 pound at P supports 8 pounds at W. If another movable pulley were added, the 1 pound at P would support 16 pounds; and so on.

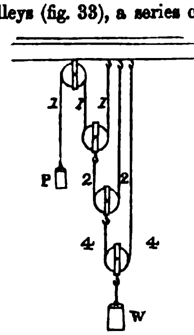


Fig. 33.

In working pulleys, the power must be applied in a line perpendicular to, or parallel with, the weight—that is, straight above the weight—in order to produce the full efficacy of direct force. If the power be applied obliquely, there will be a loss of power in proportion as the line of draught departs from the perpendicular.

Pulleys are used chiefly on board of ships, where blocks and tackle are in constant requisition for raising and lowering the sails, masts, and yards. They are likewise in considerable use by house-builders and others, in connection with the wheel and axle, for raising or lowering heavy masses of stone and other articles.

Fig. 34 is a representation of a system of pulleys commonly used in practical operations. Three movable pulleys are enclosed in the block A, and three fixed pulleys are enclosed in the block B. Suppose, therefore, that the weight W, in this case, is 600 pounds, the hand P pulls it upwards by exerting a force of 100 pounds. A combination of pulleys resembling this is used in turning kitchen-jacks. The weight in

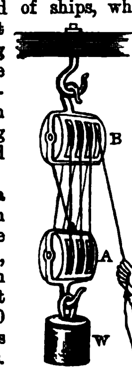


Fig. 34.

sinking draws off the cord from a spindle, by which motion the jack is turned. In order that a considerable weight falling slowly through a comparatively small height may keep the jack in motion for a long time, as many as ten or twelve movable and fixed pulleys are used.

THE INCLINED PLANE.

If AB represent a horizontal plane, AC will represent a sloping or *inclined* plane. If we suppose AC to be a plank resting on the ground at A, and with its other end at C on the edge of a dray-cart, a man can roll a heavy cask from A to C, which it would be far beyond his strength to lift perpendicularly from BC. In such a case the inclined plane is used as a mechanical power.

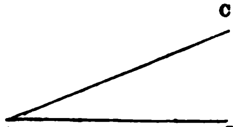


Fig. 35.

In investigating the advantage afforded by the inclined plane, we consider, as in all the other mechanical powers, what force is necessary to hold the weight in equilibrium—in other words, what force is necessary to keep the cask, when once on the plane, from rolling down. When it is once balanced in this way, a little additional force will make it move up. In practice, if the heavy body to be moved up is of a square shape, as a box, its own friction is sufficient to keep it from sliding down, unless the elevation is very great; and to push it up requires force to overcome this friction, in addition to what would be necessary to push up a round body of the same weight. But for the theory of the inclined plane, we consider bodies as moving without friction; and this is most easily conceived by representing them either as round, or as resting on wheels, because a rolling motion is attended with comparatively little friction.

When a round cylinder rests on a level plank, its whole weight is supported by the reaction of the plank, and it has no tendency to roll either way; but if one end of the plank be raised, however slightly, the cylinder begins to roll, and a certain force is required to keep it at rest. As the end is more and more elevated, the restraining force requires to be increased, and at the same time the pressure on the plane becomes less, until, when the plank comes into the upright position, it ceases to sustain any pressure, and a force equal to the whole weight of the cylinder is required to keep it in its position.

In order to find the relation of P to W in a given inclined plane, we have recourse to the resolution of

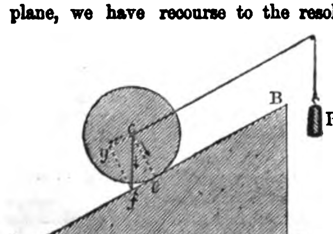


Fig. 36.

forces. In the above fig., which represents a cylinder resting on a plane, and kept from rolling down by a weight suspended over a pulley, let *cf*, drawn from the centre of gravity of the cylinder in a vertical direction, represent the whole weight of the cylinder. This force may be resolved into two others, *ce* perpendicular to the plane, and *cg* parallel to it; but *ce* is counteracted by the resistance of the plane, and can produce no effect; therefore *cg* or *ef* represents the force with which the cylinder is urged in the direction of BA, or the weight of P necessary to keep it from rolling. Now, it can be shewn that the triangle *cfe* is similar to the triangle ABD; therefore *fc* is to *ef* as AB to BD—that is, *W is to P as the length of the plane to its height.* If AB is twice the length of BD, one hundredweight at P will sustain two hundredweights at W; and if AB is six times the length of BD, W will be six times P.

In speaking of sloping roads, they are said to have an inclination or rise of one foot in ten, one in thirty, one in a hundred, and so on. The annexed cut represents

Fig. 37.

a cart drawn by a horse up a road with a rise of one in ten. On a perfectly level road, a certain force of draught would be required to overcome friction; on the incline there is required, in addition to this, a constant pull to counteract the tendency of the cart to run down the slope. That tendency is, in this case, equal to a tenth of the weight of the load; and if the load is a ton, the horse has to pull with a force of one-tenth of a ton, or 224 pounds, above what would have sufficed to draw it along a level.

In going over ten feet of the road, the horse has raised the cart one foot perpendicularly, but he has done it by instalments; the exertion has been spread over a movement of ten feet. Intensity of exertion is saved at the expense of time.

Fig. 38 represents two inclined planes of the same height, but different slopes, meeting together at the top, with a weight resting on each, P and Q, hanging by a string, which passes over the pulley M. If the length of the longest plane from A to M be two feet, and that of the shorter from B to M be one foot, then two pounds at Q, on the short side, will balance four pounds at P, on the long side; and so for other proportional lengths. In this manner, weights moving on two adjoining inclined planes may be adjusted so as to balance each other, although the inclinations be different; and they are so made to act on various sloping railways, where one wagon descending on one plane, is made to draw up another wagon on another plane.

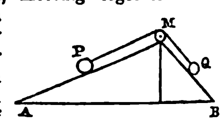


Fig. 38.

In modern times, roads are constructed with as few risings and fallings as possible. When roads have necessarily to be carried to the summits of heights, they are made either to wind round the ascent, or to describe a zigzag direction. The drivers of carts are aware of the saving of violent strain to their horses by causing them to wind or zigzag up steep roads, instead of leading them directly forward.

Fig. 39.

The inclined plane is resorted to in many of the ordinary occupations of life. By it, loaded wheel-barrows

are with comparative ease wheeled to considerable elevations in house-building and other works of art; hogsheads are rolled out of or into wagons, and ships are launched into or drawn from the water, the inclined plane being as useful in giving facilities for letting down loads as in drawing them up.

THE WEDGE.

A common form of the wedge is represented in the figure. By forcing such a body below the bottom of an upright post, for instance, which can move only vertically, we may raise it a few inches. It obviously acts on the principle of the inclined plane; it is, in fact, the inclined plane made movable. A wedge of the ordinary shape is really two inclined planes placed base to base.

Fig. 40.

The proportion of the power to the resistance in the wedge is calculated theoretically in the same way as in the inclined plane. But the theory is of little or no value. The power employed being percussion or blows, cannot be rightly compared with the resistance; it cannot be estimated in pounds, like other forces. The friction, too, is so great as to render any precise statement of proportion impossible. In a general way, however, the wedge is more powerful as the angle is more acute; just as the advantage of the inclined plane increases with the smallness of its height.

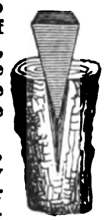


Fig. 41.

The wedge is used in splitting timber, stones, &c. Ships are raised in docks by driving wedges under the keel. In expressing oil from seeds, the seeds are placed in bags between solid pieces of wood, and these are forced together by means of wedges, till the seeds become a mass as compact as wood.

Cutting and piercing instruments all act on the principle of the wedge. The plough is also an instance.

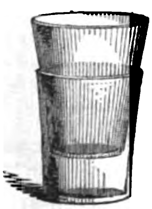


Fig. 42.

The principle of the wedge operates in the case of two glass tumblers, one placed within the other, as in fig. 42. A very gentle pressure applied to the uppermost tumbler would be sufficient to burst the lower.

THE SCREW.

The screw is an inclined plane wound round a cylinder, resembling the spiral road winding round the hill in fig. 39.

Take a cylindrical ruler AB, and cut a slip of paper in the form of a right-angled triangle *abf*, having *ab* equal to the length of the cylinder, and *bf* equal, say to four times its circumference. If the edge *ab* is

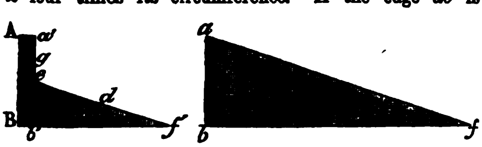


Fig. 43.

applied to the cylinder lengthwise, and the triangle is then wrapped round and round, the slanting side, *af*, will form a spiral going four times round the cylinder before it reach the bottom. In the fig. to the left of the cut, it is represented as half wrapt on.

If a ridge or projection were raised on the cylinder along the spiral line, it would form a screw. The several turns or coils of the spiral are called the *threads* of the screw; *ed* represents the *length* of one thread, and *ec* the *distance between the threads*. In moving over a complete round of the spiral, a perpendicular ascent or descent is made equal to *ec*. As in the inclined plane, therefore, the mechanical advantage of the screw must be greater in proportion as the length of a thread exceeds the distance between two contiguous threads.

In using the screw as a machine, the resistance is not applied directly to the spiral surface, as in the wedge or the straight inclined plane; the screw is made to work in a hollow cylinder with spiral grooves cut out to correspond to the projecting threads. This concave screw is technically called a *nut*, as represented at M, fig. 44. The threads and corresponding grooves are sometimes of a triangular form, as in fig. 44; and sometimes flat, as in fig. 45.

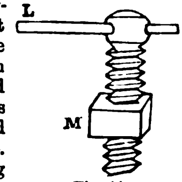


Fig. 44.

To produce pressure with the screw, either the screw or the nut must be fixed. Whichever is free, is then turned, and made to press against the resistance.

Practically, the screw is never used as a simple machine; the power being always applied by means of a lever, passing either through the head of the screw or through the nut. The screw therefore acts with the combined power of the lever and inclined plane; and in investigating the effects, we must take into account both these simple mechanical powers, so that the screw now becomes really a compound machine.


Fig. 45.

To arrive at the proportion of the power to the weight in this compound machine, we may apply the principle of virtual velocities. The power acts at the end of the lever L (fig. 44), and in turning the screw once round, it describes a circle, of which the lever is the radius. The circumference of this circle represents the velocity of the power. In the meantime, the weight has moved over a space equal to the distance between two threads, which is its velocity. Now, the power multiplied by its velocity, is always equal to the weight multiplied by its velocity; therefore, *in the screw, the power multiplied by the circumference it describes, is equal to the weight multiplied by the distance between two contiguous threads.*

The length of the lever of a screw is forty inches—counting from the centre of the screw—and the distance between the threads is one inch; what power will produce a pressure of 8000 pounds? The diameter of the circle described by the power is here eighty inches, and the circumference may be taken, in round numbers, at three times that, or 240 inches. The product of the weight into the distance between two threads is $8000 \times 1 = 8000$; the power must therefore be $8000 \div 240 = 33\frac{1}{3}$ pounds. This, however, is only in theory; in practice, the power must be increased by a third, for the purpose of overcoming the friction; it would in this case, then, be about forty-four pounds.

It is evident that the power of a screw increases with the closeness of its threads—that is, with its fineness; but this way of augmenting the force soon comes to a limit, because the threads, if too fine, bend or break off—the screw overdraws. To obviate this is the object of a contrivance called, from its inventor, the Hunterian screw. It consists of two screws whose threads differ slightly in breadth. The smaller of the two is made to work into the other as a nut, and one turn of the outer screw in its nut advances the end of the inner screw by a space equal to the difference between the breadths of the two sets of threads. Thus, if there are six threads in the inch of the outer screw, and seven in the inner, the advance caused by one revolution is $\frac{1}{6} - \frac{1}{7}$, or $\frac{1}{42}$ of an inch. The power is thus the same as if the screw had been single, with forty-two threads in the inch; while at the same time the threads are large and strong.

The most common purpose for which the screw is applied in mechanical operations, is to produce great pressure accompanied with constancy of action, or retention of the pressure; and this quality of constancy is always procurable from the great friction which takes place in the pressure of the threads on the nut, or on any substance, such as wood, through which the screw penetrates. The common standing-press used by bookbinders for pressing their books affords one of the best examples of the application of the screw to produce great pressure (fig. 46). The screw A has a thick round lower extremity B, into holes in which the lever is inserted. This extremity B is attached by a socket-joint to the pressing-table C, so that when the screw is turned in one direction, the table sinks, and when turned in another, the table rises. The books D lie upon a fixed sole S, and are thus between the table and the sole. H is a cross-beam above, in which is the box or overlapping screw, to give the necessary resistance.

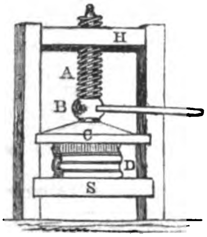


Fig. 46.

The force of the screw is sometimes employed to turn a wheel by acting on its teeth, by which means there is a combination of two mechanical powers — the screw, and the wheel and axle (fig. 47). The screw is upon the horizontal spindle, and by turning it by the handle, each turn of the thread receives a tooth of the wheel, and brings it forward, so as to produce a perpetual revolution of the wheel. This is called an endless screw, because it never stops in its action; no sooner is one turn of the thread disengaged, than another has come into operation. W represents a weight to be raised hanging from the circumference of the axle.

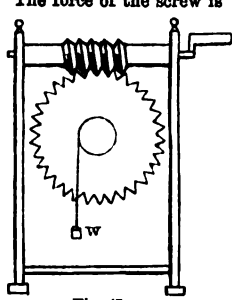


Fig. 47.

STRENGTH OF BODIES AND OF STRUCTURES.

A knowledge of the simple principles of mechanics above considered, together with that of the general properties of matter, enable us to determine what forms of bodies and what positions are best calculated to resist forces that tend to break, crush, or overthrow them. This constitutes engineering. A few of the more important general truths thus arrived at may be here noticed; their applications are treated of in a separate number.

One regards the best shape of a beam to resist a transverse strain—that is, a force tending to break it across. When a rod of wood is suspended vertically, and a weight attached to it tending to tear it asunder, all its fibres act equally, and its strength evidently depends on the strength of the individual fibres and their number—that is, the area of the cross section of the rod. If there are two rods, then, of the same material, the one having an area of one square inch in its cross-section, the other an area of three square inches, the last will sustain three times the weight that the other will sustain, and this whatever be the shapes of the sections. The section of the one rod may be circular, square, oblong, triangular, &c., and that of the other any other shape.

But it is different when a rod or beam resists a force laterally. In fig. 48, a beam is represented supported at the two ends, and breaking by a weight resting upon it. The fracture opens as if a hinge were placed at *d*; and if we consider *ge* and *hf* to be two fibres drawn out by their elasticity just before their rupture, we see that they exercise very different forces in resisting the

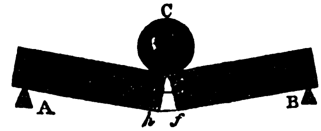


Fig. 48.

fracture of the beam. *hf* acts at the ends of the long levers, *hd* and *fd*, while *ge* acts at the ends of levers of half the length. The effect of any fibre, then, in resisting the fracture, is equal to its absolute strength multiplied by its distance from *d*; and their collective effect is equal to the sum of their absolute strengths multiplied by their *mean* distance—that is, by the distance of the centre of gravity of the section below the point *d*.

Let A and B represent sections of two beams, A being a square of ten inches each way, and B having half the breadth and twice the depth. The number of fibres in each is as the area; and the area of A is $10 \times 10 = 100$; of B, $20 \times 5 = 100$. But the effective force of the fibres is as their number multiplied by the distance of the centre of gravity from the end of the fracture. The strength of A, therefore, is 100×5 (the length of *cg*) $= 500$; and that of B is 100×10 (the length of *dg*) $= 1000$. The beam B has thus double the strength of A, although they both contain the same quantity of material. It is on this principle that the rafters of floors, roofs, &c., are not made square, but as deep and thin as may be without yielding laterally. Strength is thus gained and material saved.

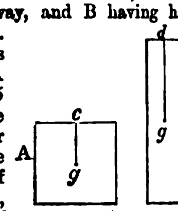


Fig. 49.

For the same reason, a hollow cylinder is stronger than the same material made into a solid rod. B is the section of a hollow cylinder, the thickness of whose walls is represented by the shaded ring; A is the section of a solid cylinder of the same material. If the area of A is equal to that of the ring in B, the two cylinders will contain the same quantity of matter, but B will be stronger than A in proportion as *cg* is longer than *dg*; *g* being the centre of gravity of the ring, *cg* is the average advantage or leverage at which the cohesion of the matter of B acts in resisting fracture, as *dg* is the leverage in A.

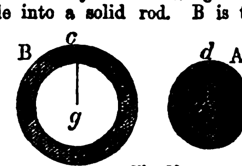


Fig. 50.

It is evident that if the hollow is placed, not in the middle, but nearer the side where the fracture would end, the strength will be increased, because the centre of gravity is thrown to a still greater distance. The limit to this, as well as to the enlargement of the hollow generally, is that the walls must be left thick enough to be rigid and preserve their form.

The principle of hollow structure prevails both in nature and art, wherever strength and lightness have to be combined. It is seen in the stems of plants, especially of the grasses; the bones of animals are also hollow, and those of birds, where great lightness is required, are most so. A feather, with its hollow stem, is perhaps the best instance of the union of strength and lightness that could be given. In art, again, we have hollow metal pillars. And in tubular bridges, the sides, bottom, and roof do not consist of one layer of metal, but of a series of cells or hollows, so that every part has as much lever-power as possible, to resist bending and fracture. Iron ships are now built on the same principle.

Another general truth respecting the strength of

bodies and structures is, that the larger the scale anything is constructed on, the weaker proportionally it is; and the greater tendency it has to fall asunder by its own weight. If the dimensions of a beam are doubled in every way, its strength to resist external pressure is increased fourfold; or the strength increases as the *square* of the dimensions. But by doubling the dimensions, the weight becomes eightfold what it was, or increases as the *cube* of the dimensions. A point is thus soon arrived at where, instead of supporting external force, a beam breaks with its own weight.

This important principle limits the size of machines, buildings, ships, &c.; as well as of trees and animals. The larger an animal is, its limbs are, out of proportion, thicker; the clumsiness of the elephant shews that a much greater size could not exist on our globe. The giants of fable are impossible beings. A small compact man is stronger in proportion to his size than a tall man.

PRACTICAL MACHINERY.

The term *machine* is ordinarily applied to any piece of mechanism in which different parts are combined to produce a desired effect. In NATURAL PHILOSOPHY, a machine of this nature is called a *complex machine;* and the treatment of the principles on which complex machines operate, constitutes that department termed PRACTICAL MACHINERY.

The simple mechanical powers compose the elements of all machines, however complex or extensive. Thus, in all machines, levers, cords, or inclined planes, in their different modifications, are found to be the elementary parts, combined in harmonious union to accomplish certain results.

This department may be treated of under three divisions. 1. The component parts of machines, shewing the method of practically adapting the principles of the mechanical powers; this may be called the department of *construction*. 2. The arrangement and combination of these parts, to effect the variety of mechanical movements for changing the direction or application of motion or force. 3. The scientific principles upon which the various parts are constructed. The first two of these divisions comprise what may be called the department of *mechanical design*, or arrangement, and will be discussed in the present paper only; the last will be found in the paper on MECHANICAL ENGINEERING.

The following are the principal component parts of machinery:—

Shafts.—The axles on which wheels and pulleys are supported are termed *shafts* and *spindles;* the former being applied to axles of large, the latter to those of small dimensions. Shafts are of two kinds—*horizontal* and *vertical*. In fig. 51, *abc* is part of a horizontal

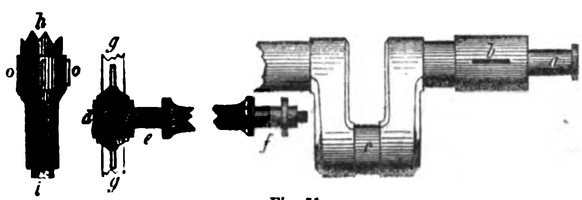


Fig. 51.

shaft; *hi* part of a vertical. The latter is generally used for conveying motion from the lower to the upper part of a machine, or from one story of a mill or factory to the other. The part of a shaft on which it revolves is termed the *journal* or *bearing;* in heavy mill-shafts it is termed sometimes the *gudgeon*. In fig. 51, *a* is the journal of the horizontal shaft *abc*. The journal is formed by turning the shaft to a less dimension than the adjacent parts; thus forming a projection at each end. These projections, as at *f*, are called *ruffs* or *collars*. The part of the shaft on which the wheel is to be fixed is termed the *boss*, as *b* in the horizontal shaft *abc*, and *oo* in the vertical one, fig. 51. The wheel or pulley is fastened firmly on by what are called *keys*, driven into grooves made in the eye, and termed *key-seats*. In fig. 51, *fed* is part of a spindle or small shaft; *f*, *e* are the journals, *d* is the boss, *gg* represents part of a pulley keyed on to the boss. In *hi*, which is part of a vertical shaft, *oo* is the boss, and *i* the bearing.

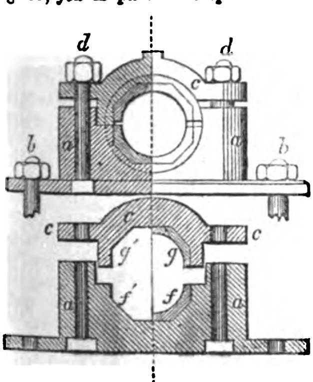


Fig. 52.

Pedestals, or Plummet-blocks, for Horizontal Shafts.—To support the shafts while in motion, *pedestals* or *plummet-blocks* are used. In fig. 52, towards the right-hand side of the centre line of the upper figure, we give a half front elevation of a plummet-block or pedestal; *aa*, the body, is bolted down to the base of the machine by the bolts *b*, *b*. The journal of the shaft is embraced by what are known as *brasses*, *bushes*, or *steps*, made in two pieces or halves, as *g'g*, *f'f*. Fig. 53 gives different views of the brasses: *a* is a front view of the upper brass, *e* a side elevation of the same, and *a'* a section; *b* is an elevation, *d* a side view, and *b* a section of the lower brass; *e* is a plan of both the upper and lower brasses. The breadth of pedestal, body, and cap is such, that they go easily within the projecting flanges, *f*, *f*, of the brasses, as shewn in fig. 53: the brasses are thus prevented from sliding out laterally from the block, as they would be apt to

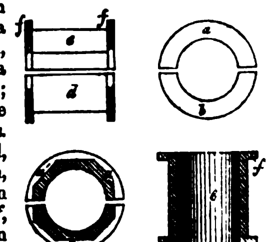


Fig. 53.

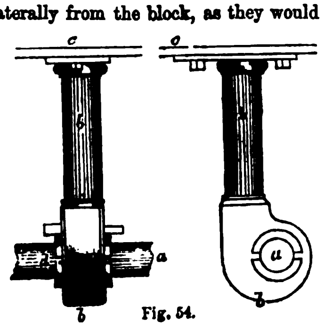


Fig. 54.

do if not furnished with flanges. Shafts are sometimes

required to revolve beneath the ceiling, in order to convey power from one point to another of a building, without interfering with arrangements on the floor below. In this case, *hangers* are used, as shewn in fig. 54. Let *cc* represent the line of ceiling; the suspension bearing is bolted to this, as *bb*: *a* represents the shaft, *d* the brasses in which it revolves.

Steps or Bearings for Vertical Shafts.—A brass block *e*, fig. 55, is placed in the interior of a cast-iron box *bb*, *aa*, which is bolted firmly down to the base, on which the step is supported, generally a block of stone. The position of the brass block *e* is adjusted accurately within the box, so as to make the shaft perfectly vertical, by the adjusting screws *b*, *b*. A hollow is made in the brass *e*, in which the end of the shaft, as *i*, fig. 51, revolves; it being well lubricated by oil poured in, or by tallow which is placed in a space furnished for it in the side of the brass *e*.

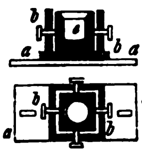


Fig. 55.

Couplings for Shafts.—When the distance to which motion is to be communicated is too great for the employment of one shaft, the several lengths required are joined together by contrivances known as *couplings*. The round coupling, which is most generally used, is illustrated in fig. 56: this, from one end locking into another by the *half-lap joint*, forms a secure coupling. The coupling-box, *c*, is fastened on either by means of *keys*, or by two pins passed through the box and the shaft at right angles to each other, and firmly riveted into countersunk holes made in the box, as shewn at *ac*.

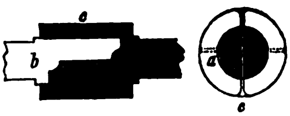


Fig. 56.

Toothed Wheels.—Toothed gearing is divided into two classes—1. spur-wheel; 2. spur-wheel and pinion, and bevelled gear. Fig. 57 represents two spur-wheels in

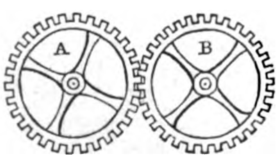


Fig. 57.

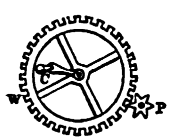


Fig. 58.

gear; fig. 58, a spur-wheel and pinion; and fig. 59, two bevelled wheels in gear. For a brief investigation of

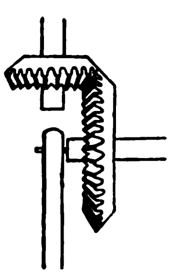


Fig. 59.

the principles which regulate the construction of toothed wheels, see section on Machinery, in the number on MECHANICAL ENGINEERING.

Pulleys.—When motion is transferred from one point to another by means of belts, chains, &c., pulleys are used. In fig. 60, *a* is the front, and *b* the edge view of the pulley used with the flat leather belt. The periphery of the pulley is made convex; this prevents the belt from slipping off, as its tendency is always to keep to the highest part: *c*, *e*, are sections of a pulley, shewing the method of fixing on the shaft; *d* is the form of pulley

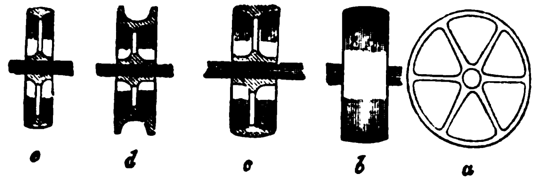


Fig. 60.

used when chains or ropes are made to transmit the power.

Ratchet-wheels.—It is sometimes necessary to prevent wheels and axles, bearing the strain of heavy weights, from flying in a backward motion after being wound up. This purpose is effected by fixing a ratchet-wheel to the extremity of the axle. This wheel has teeth all round its periphery, inclining in one direction; and a small catch is so placed as to enter the indentations, and stop the wheel if it inclines to turn backwards; but the catch slides over the teeth without obstructing them, if it moves forward. A spring pressing on the catch causes it to keep in its proper place (fig. 61).

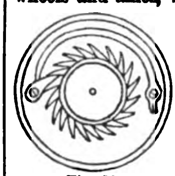


Fig. 61.

Cranks.—A crank resembles a common handle or winch for turning a machine by the hand; the chief difference being that a rod or shaft jointed to the handle, and going up and down, works the machine. Fig. 62 represents a double crank in action. S is the rod or shaft ascending and descending, and attached by a joint to the lower part of the crank C, which it alternately pulls up and pushes down, so as to cause the axles W, W to turn a wheel at each side. Take away one of the sides of the crank and its support, and the apparatus becomes a single

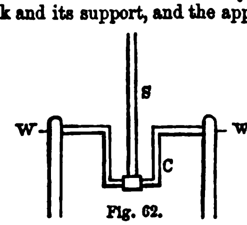


Fig. 62.

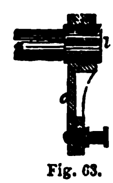


Fig. 63.

crank. In fig. 63, we give a section of the crank of a steam-engine. *c* is the crank keyed on to the boss *b* of the shaft *a*; *d* is the crank-pin, to which the connecting-rod is attached, which gives motion to the crank-shaft *a*.

Connecting-rods.—In various mechanical movements,

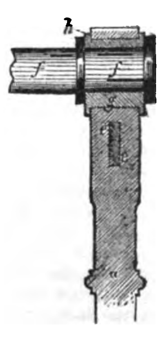


Fig. 64.

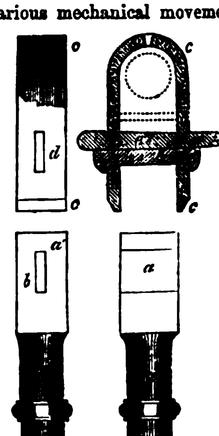


Fig. 65.

motion is communicated from one point to another by

means of connecting-rods. The details of this part of mechanism are shewn in figs. 64, 65, and 66. In fig. 65, *aa* is the front view of *butt* of upper end of connecting-rod, and *a'a'* the side view; *cc* the side view of the strap, and *c'c'* the front view. The journal *f*, fig. 64, is embraced by two brasses, the upper of which is shewn at *a*, fig. 66, and the lower at *b*; *a'* and *b'* being side views of these: in fig. 64, *g* is the lower, and *f* the upper brass. An inspection of the figures will shew how the whole are put together.

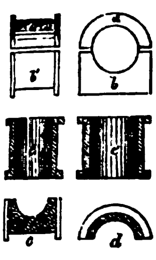


Fig. 66.

Eccentrics.—An eccentric is a wheel or pulley, with the axis out of the true centre. The construction of this is shewn in fig. 67. It consists of a pulley *aa*; the

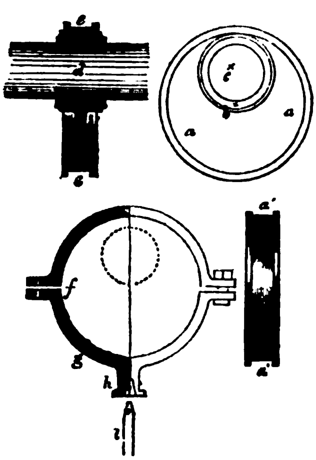


Fig. 67.

periphery of which is grooved, *a'a'*. The true centre is at *b*, but the working-centre, or that through which the axis or shaft *d* passes, is at *c*. In the course of its revolution, any point on its circumference will alternately rise and fall; the extent of which rise or fall is just double the distance which the centre *c* is from the true centre *b*. This alternate motion is communicated to the shaft or lever *l*, by causing two rings, *f*, *g*, to the lower of which the lever *l* is fixed by insertion into the part *h*, to embrace the periphery *a'a'* of the eccentric, so as to allow it to revolve easily within the rings or hoops. The motion is thus communicated to them without causing their revolution.

MECHANICAL MOVEMENTS.

Altering the Direction of Motion.—The use of bevel-wheels, as illustrated in fig. 59, is a very common mode of changing the direction of motion, the horizontal motion of one shaft giving the vertical motion of another.

Where two pulleys work together by means of belts or driving-straps, the driven pulley moves in the same direction as the driving: to change the direction of the driven pulley, all that is necessary to be done is to cross the belt, as illustrated by fig. 68. The same change of direction is effected by using spur-wheels, as in fig. 57; the driven wheel revolving in the opposite direction from that of the driving.

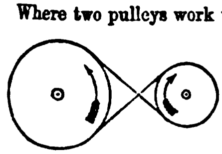


Fig. 68.

Altering the Velocity of Motion.—Where the driven shaft is required to move at a different velocity to that of the driving, it may be effected either by the use of pulleys or toothed wheels of different diameters.

Any degree of velocity greater than that of the first rotary motion, may be imparted to the parts of a machine, by making these parts so much smaller than the primary moving parts.

Preserving the Direction of the Original Motion.—Where two wheels, as in fig. 57, gear together, they revolve in opposite directions—the driven opposite to the driving. By adopting the contrivance of the *annular-wheel*, as in fig. 69, the motion of the driven wheel *aad* is the same as that of the driving-wheel *b*. By placing a third wheel between two toothed wheels, the motion of the third wheel is the same as that of the first.

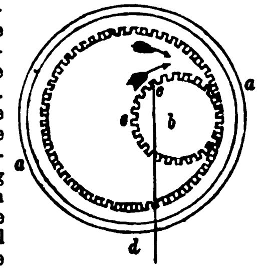


Fig. 69.

Transmission of Power from One Point to Another.—A common plan of transmitting power from one point to another, when the interval is considerable, is by a flat leather band, strap, or belt, communicating from a wheel at the source of power to a wheel connected with the machine, as in fig. 70.

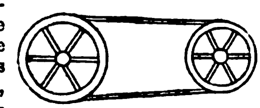


Fig. 70.

Changing or Varying the Velocity of Motion.—It is sometimes necessary that a machine, or part of a machine, should be propelled with a velocity which is not equable, and is continually changing from fast to slow, and slow to fast. This happens in cotton-mills, where it is necessary that the speed of certain parts of the machinery should continually decrease from the beginning to the end of an operation. To effect this, an apparatus is used, as represented in fig. 71. The belt is moved alternately from right to left, from one end of the drum to the other; as it thus acts on circles of continually changing diameter, it causes a continual change in the velocity of the shafts.

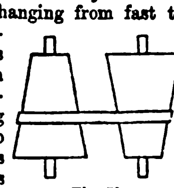


Fig. 71.

The speed-pulleys in fig. 72 is a very usual method of changing the velocity of shafts. Thus, when the belt is passed over *c* and *d*, the velocity of the shaft *fed* is less than that of *abc*; while over *a* and *f*, the condition is reversed.

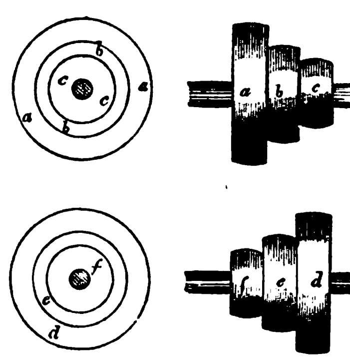


Fig. 72.

Intermittent and Alternating Motions.—Suppose the pinion *a*, fig. 73, to be furnished with teeth for part of its periphery only; the rack *b* will move only as these teeth come in contact with those of the rack. By making the pinion move alternately in different directions, the rack *b* will have an alternate motion to right and left. The stamper or weight *c*, fig. 74, will have an intermitting movement given to it by the cambs of the wiper-wheel *ab*; the weight will rise and fall twice during one revolution of the wiper-wheel *ab*.

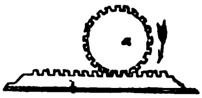


Fig. 73.

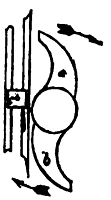


Fig. 74.

Another example of this movement is given in fig. 75. The object required is to work a heavy hammer upon an anvil for beating iron. W is the wheel with the three cambs, and it turns by an axle in upright supports. In turning, each camb, with its rounded or convex side, presses down the end of the handle of the hammer, so as to raise the heavy head H at the opposite end. After pressing down the handle, and escaping, the head of the hammer falls with a heavy blow on the anvil A. There it remains till raised up and let fall by the next camb; and so on.

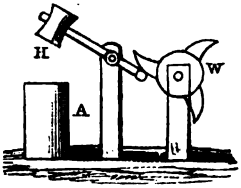


Fig. 75.

The lever *ac*, fig. 76, will rise and fall through a space equal to *ab* during the revolution of the heart-shaped wheel or camb, the centre of which is *b*.

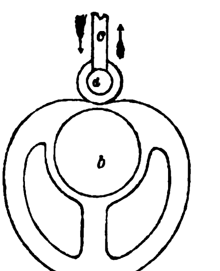


Fig. 76.

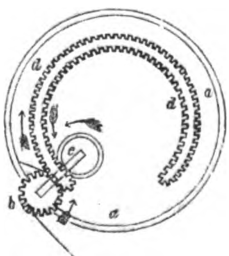


Fig. 77.

An alternate motion from one side to another is given to a drum, or horizontal drum or pulley, *aa*, fig. 77, by the contrivance known as the *mangle-wheel motion.* To the face of the pulley a double circular rack, *dd*, is attached; the axis of the pinion *b*, which gears into this rack, is allowed to traverse in a slot, so that it will, on reaching the end of the outside rack, pass round the teeth of the curved ends, along the slot, and gear with the teeth of the inside rack. By giving a continuous motion to the pinion *b*, it will engage with—say the teeth of the outside rack—thus moving the rack and pulley in the opposite direction; but as soon as the pinion gears with the teeth of the inside rack, the direction of both is the same (see the annular-wheel, fig. 69); and the pulley thus moves in an opposite direction.

To change Reciprocating into Circular Motion.—By the crank. The reciprocating movement of the piston-rod —the parallelism of which is preserved by the cross-head sliding between the guides—is changed into the circular one of the fly-wheel by the crank fixed to the fly-wheel shaft and the connecting-rod. To admit of the movement of the rod from right to left, and *vice versâ*, it is jointed to the crank-pin at one end, and to the piston-rod cross-head at the other. An exemplification of this will be found in the crank overhead-engine in the paper on the STEAM-ENGINE. The continuous circular motion of the fly-wheel of a knife-grinder's wheel is produced from the alternate rising and falling of the foot of the operator, acting on the footboard by the intervention of the connecting-rod and crank. The sun-and-planet wheel motion was used by Watt to change the reciprocating motion of the piston-rod into the circular one of the fly-wheel. To the end of the connecting-rod a toothed wheel was firmly fixed; this geared with another wheel of the same size, fixed on the fly-wheel shaft; the centres being connected with a jointed link. The connecting-rod, as it rose and fell, carried the wheel at its extremity round the periphery of the wheel fixed on the fly-wheel shaft, and at the same time gave motion to it and the fly-wheel.

To change a Circular into a Reciprocating Motion.—A very general method of doing this is by the use of the eccentric, the constructive details of which we have shewn in fig. 67.

An *eccentric-wheel* is a wheel with an axis not in its centre, but at a point nearer one side than the other. Fig. 78 represents the action of a wheel of this kind. W is the wheel, and A the axis upon which it is fixed. When the axis turns, the wheel turns with it. As the axis never moves out of its place, the wheel necessarily describes a path of gradual rising and falling in its revolutions. Suppose an object, as T, pressing upon the upper edge of the wheel, so as to accommodate itself to the motion, it is obvious that, by the action of the wheel, this object will be alternately raised and allowed to fall. Or suppose that a rod is hung from a point of the wheel near where T rests, it is similarly obvious that the rod would be raised or depressed according as the wheel turned. Thus, a rising and falling motion may be effected by an eccentric-wheel.

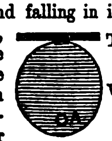


Fig. 78.

The heart-shaped wheel or eccentric *b*, fig. 76, is another method of producing reciprocating from circular motion; as also the rack and pinion, fig. 73.

To change a Reciprocating Circular Motion into a Reciprocating Rectilineal.—The well-known parallel motion of Watt is a familiar exemplification of this movement.

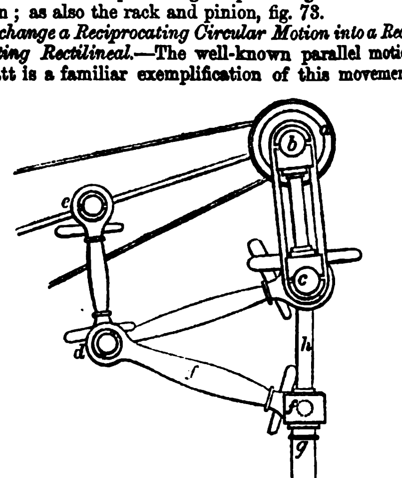


Fig. 79.

Let *ea*, fig. 79, be the beam; to two studs or centres in the direction of its length, two links of equal length are jointed at one end, as *be*, and at the other to another link *cd*, which is always parallel to the line of centre of *ea*. A lever, *f*, is jointed at *d* at one end, and at the other to a stud on a fixed support *g*. The end of the piston-rod, *h*, is fixed to a cross-head or bar jointed with the ends of the lever *cb*. On the other side of the beam a similar set of levers are arranged. The piston-rod *h*, in this arrangement, moves in a straight line, while the

end of the beam, *ea*, moves in the arc of a circle.—A continuous circular motion is changed into a reciprocating rectilineal one by the contrivance known as *White's parallel motion*. This is illustrated in fig. 69, and proceeds upon the principle, that if a pinion *b*, of diameter equal to the radius of the annular-wheel, *aa*, be made to roll within the fixed annular-wheel, a point *c*, in the pitch circle of the pinion *b*, will describe a right line. If, then, the end of a piston-rod be attached to this point, it will move in a straight line.

Accumulating and Equalising of Power.—Power is susceptible of *accumulation*—that is, of increasing little by little—and of being expended either gradually or in one or more violent efforts; the efforts being entirely the concentrated amount of the previous accumulation.

In consequence of this convenient accumulation of power in machines, plans have been devised for establishing *reservoirs of power*, as they may be called, in connection with moving machinery.

In contrivances in the arts, power is sometimes accumulated in order to be given out in the form of a rapid and effective blow. This may be done by means of a horizontal bar or lever, poised on a central axis, and loaded at each end with a heavy ball of lead or iron. After communicating to the machine a sufficient power of rotation, it will proceed with an enormous accumulated energy and momentum, till it expend its force either by friction in turning, or upon some fixed obstacle presented to it.

The press used for stamping or taking impressions of coins and similar articles from dies, furnishes one of the best examples of the instantaneous expenditure of accumulated power. A press of this kind is represented in fig. 80.

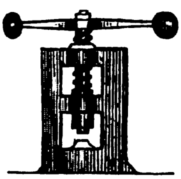


Fig. 80.

In most machines, both the moving force and the resistance to be overcome are liable to fluctuations of intensity at different times during the operation of working.

The irregularities in the motion of machinery, from whatever cause they arise, are remedied by giving to each machine a *reservoir of power*, from which force may be given at all times to equalise the motion, according as it may be required. These reservoirs of power are usually in the form of *fly-wheels*.

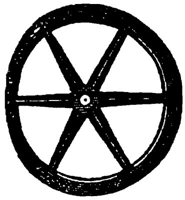


Fig. 81.

A fly-wheel is generally made of iron, and consists of a heavy rim or circumference, joined to a central axis by cross-bars or spokes (fig. 81). In most cases, it is placed in close connection with the first moving force, the effect of which it equalises in its passage to the machine.

Regulation of Power.—In some mechanical contrivances, the force which is applied varies in its intensity, while the wheels of the machinery require to be kept at a uniform speed. This is generally the case when the force is communicated from a steel spring, which, after being wound up, is suffered to relax. Fig. 82 is a spring suited for operations of this kind. It is represented in a state of relaxation, and is wound up into a compact form by means of a spindle fixed to its inner extremity.

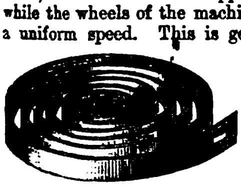


Fig. 82.

The force communicated by the relaxing of the spring varies in its intensity. The force is greatest when it begins to relax, and it gradually weakens till its expansive energy is exhausted. To compensate this defect, a very ingenious plan is adopted, and which is put in operation in the apparatus of the common watch.—

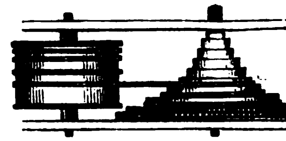


Fig. 83.

Fig. 83 represents the apparatus of motion in a watch, somewhat magnified.

In proportion as the intensity of the force weakens, and the barrel takes off the chain from the fusee, and winds it about itself, so does the chain act upon a longer lever, or so does it gain a greater lever-advantage, by drawing at a wider part of the cone. Thus the gradual loss of force is counterbalanced by a gradual increase of lever-advantage. (The case resembles that of a strong man working with a short lever, and a weak man working with a long lever; both are equal in effect in balancing any resistance.) The wheel-work of the watch is moved by teeth on the lower circumference of the cone.

The steam-engine governor is another method of regulating the speed of a machine.

Engaging and Disengaging Machinery.—The most common and simplest device used in cases of motion by belts, consists in having a *fast* and *loose pulley*. Alongside of the pulley whose axle moves the machinery, and on which the belt works, there is a pulley or wheel loose on its axle, called the loose-pulley, from its inoperative character. When the machine is to be stopped, the belt is shifted from the fast or active pulley to this loose-pulley, which it turns without producing any effect on the machinery. Motion is restored to the machine by shifting the belt back to the fast-pulley. A long rod, with a clutch at its extremity, and easily affected by the hand of the workman, turns the belt off or on at a moment's notice.

Another method of engaging and disengaging machines is by the use of the sliding-clutch, or coupling. Let *a*,

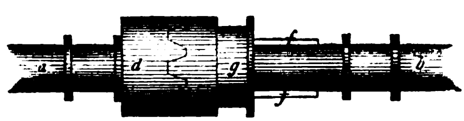


Fig. 84.

fig. 84, be the driven shaft, or that which takes the motion to the machine; and *b* the driving-shaft. To *a* a coupling-box is fixed, with projections and indentations on its face; a clutch, with corresponding indentations, &c., is capable of sliding along the shaft *b*, on two feathers or ribs projecting from its surface, but which revolves with the shaft. This clutch is moved to and from the fixed clutch *d* by a lever, the fork of which embraces the journal *g* of the clutch *dg*. When the clutch *d*, which is carried round by the shaft *b*, is moved along the feathers, so that its projections go into the indentations of the clutch *g*, and the two become locked together, the shaft *a* partakes of the motion of *b*. The two are kept in contact by the lever which moves *g* being placed against a stud; by releasing it from this stud, the lever can be moved, and the clutch *g* thrown out of connection with *d*, and the motion of *a* thus stopped.

OBSTACLES TO MOTION.

Moving bodies, as machines and wheel-carriages, are less or more retarded in their velocity by friction, and the resistance of the atmosphere, while vessels moving on water are retarded by the resistance both of the atmosphere and of the liquid in which they are buoyant.

Friction.

Friction is an effect of the action of rubbing of bodies one upon another.

This effect is produced by inequalities of surface. No such thing is found as perfect smoothness of surface in bodies. In every case there is, to a lesser or greater extent, a roughness or unevenness of the parts of the surface, arising from peculiar texture, porosity, and other causes; and therefore when two surfaces come together, the prominent parts of the one fall into the hollow parts of the other. This tends to prevent or retard motion. In dragging the one body over the other, an exertion must be used to lift the prominences over the parts which oppose them, and this exertion is similar to that of lifting or drawing of bodies up inclined planes, or over upright protuberances. The effect so caused is called *friction*.

Friction acts as a retarding influence in the action of all mechanical contrivances, and a due allowance must in every case be made for it. In many instances, it destroys more than a half of the power employed, and seldom destroys less than a third. This latter is the usual allowance made in calculating machine labour.

The action in overcoming friction being of the nature of lifting or drawing of bodies up inclined planes, gravity is permitted to have an effect in the drawing of bodies upon horizontal planes not perfectly smooth. Thus *weight* forms an important element in calculating the probable amount of friction of a body.

Friction is found to depend on the following circumstances:—*1st*, The degree of roughness of the surfaces. *2d*, The weight of the body to be moved. *3d*, The extent of surfaces in certain bodies presented to the action of friction. *4th*, The nature of the bodies. *5th*, The degree of velocity of the motion. *6th*, The manner of the motion.

Roughness.—It is of the utmost importance to smooth the surfaces. An apparently insignificant piece of matter, or even particles of dust, will greatly retard the motion of a body.

Weight.—Friction always increases in exact proportion as the weight increases, when all other circumstances remain the same. Any moving part of machinery, therefore, should be made as light as possible, consistent with strength and durability.

Extent of Surfaces.—Rough bodies are more easily drawn along when their surface of contact is narrow than when they are broad. For example, it is easier to draw two narrow brushes across each other than two broad ones of the same weight. Friction may therefore be diminished in rough bodies by lessening the extent of surfaces in contact. But there is a limit to this diminution. If the moving surface be very thin, and the other surface soft, the thin surface will plough a groove in the soft one, and thus the friction will be increased, and the machine injured. In the case of smooth hard bodies, extent of surface makes little difference in the friction.

Nature of Bodies.—It is a remarkable truth, that two bodies which are of the same nature, or homogeneous, produce greater friction in movement than bodies which are different in their nature, or heterogeneous. This arises from the natural cohesiveness of particles of the same material. Thus, iron working against iron, steel against steel, or brass against brass, causes in each case greater friction and wearing of parts than when iron or steel is made to work against brass. This circumstance is always attended to in the construction of machinery.

Degree of Velocity.—Friction is a uniformly retarding force, except in the case of small velocities, when it is greater in proportion. The reason of its being greater in small velocities is, that in these cases time is allowed for the prominences of the moving body to sink deeply into the hollows of the surface on which it is moving, which has a retarding effect.

Manner of the Motion.—The least advantageous manner in which one body can be moved upon another, is to cause it to slide or drag. The most advantageous manner is to cause it to roll or turn. The causing of a body to roll instead of to slide, is one of the chief means of diminishing friction.

Various plans have been tried to modify the friction of wheels in their sockets. One remedy consists in constantly keeping up a fresh lubrication from small reservoirs of oil placed in the axles or gudgeons, and which supply the deficiency as it occurs. A more effectual plan consists in surrounding the inner sides of the gudgeons with small wheels, upon the rims of which wheels the axle works in turning. These *friction-wheels*, as they are called, save the axle from rubbing on the inner surface of the gudgeons, and transfer the friction to their own small axles.

Uses of Friction.—Whatever may be the retarding and frequently inconvenient effects of friction in reference to the action of mechanism, it is certain that friction is indispensable in the economy of both nature and art. It is a property which is frequently necessary in order to allow one kind of matter to possess a hold upon another without actual cohesion. One familiar use of friction is felt when we attempt to walk on ice. In order to keep our feet from sliding when on ice, if we received any impulse, we either tie rough substances on our shoes, or scatter ashes in our path, and thus we receive the benefit of friction. It is by friction that rains wear down hills, and that rivers wear away their banks, by which ceaseless process the external configuration of the globe is constantly undergoing a change. The operations in art of washing, cleaning, scouring, sharpening, polishing, cutting, bruising, beating, and so forth, are all effected less or more by friction. The hold which one fibrous substance has on another, or mutual friction, permits the operations of weaving cloth, twisting ropes and threads, and the tying of one body to another. Thus friction is of universal service; and the only known instances in nature in which it is not required, and therefore not present, are the movements of the heavenly bodies, which, so far as has been determined, revolve in a vacuum, and are consequently not impeded in their motions.

Resistance of Air and Water.

Atmospheric air and water are fluids of different densities, but both present an obstacle to the motion of solid bodies through them.

There is a rule in respect to the resistance presented in moderate velocities which applies both to air and water: it is, that *the resistance is proportional to the square of the velocity*. For example, a velocity of twenty miles an hour causes a resistance four times greater than a velocity of ten miles an hour; for the square of twenty—which is 20 times 20, or 400—is four times the square of ten—which is 10 times 10, or 100. Thus, by increasing the velocity of bodies through the air or water, we must increase the power in a greater proportion, in order to compensate the loss caused by resistance.

Resistance to motion in fluids is greatly modified also by the form of the moving body. The form that gives least resistance is nearly that of a parabola, or a form somewhat resembling the breast of a duck, the head of a fish, or the rounded bow of a vessel, sharpened to cleave the fluid through which the body passes. The body should also taper backwards, like the body of a fish.

For a classification of the different machines in use, the sources of moving power, and a description of the method of estimating their power, see the number on MECHANICAL ENGINEERING.

HYDROSTATICS—HYDRAULICS—PNEUMATICS.

MANY important properties of bodies depend upon the form or state in which they exist. Thus the properties treated of under Mechanics are such as arise chiefly from the *solid* state of bodies. But consequences, scarcely less important, arise from the other two forms in which matter presents itself—from the *liquid* condition of water, for instance, and the *gaseous* or aëriform condition of air; and these form the subjects of the present treatise.

All matter that we are acquainted with presents itself in one or other of the three forms mentioned; and the same substance may generally be made to assume them all in succession. Thus liquid water may become solid ice, or aëriform steam. These different *states of aggregation*, as they are called, depend upon the way in which the particles, or molecules, are united. From the fact that a force is required to separate the parts of a solid body, it is inferred that an attractive force is at work drawing or holding them together—the attraction of *cohesion*. From the fact, again, that force is necessary to restrain the molecules of a gas from separating further than they are, it is inferred that a repulsive force is at work among them. Attractions and repulsions, thus acting between the ultimate molecules of bodies, are called *molecular forces*. Since the same body can generally exist both as a solid and as a gas, it is assumed that both forces are inherent in the molecules of all substances. When the attractive force preponderates, the solid state is the result; when repulsion preponderates, the gaseous state results; an equilibrium of the two forces produces a liquid.

Liquids and gases agree in this, that their particles seem at liberty to glide about among one another without friction; they *flow*, and hence both classes of bodies are called *fluids*. There are all degrees of fluidity. Some fluids are thick and viscid—such as tar, honey, and some metals in a state of fusion. Viscid fluids are in general not homogeneous; they consist of solid granules floating in a real fluid. Alcohol and ether are more fluid than even water. The most perfect fluidity belongs to the gases.

But what chiefly distinguishes gases from liquids, is elasticity. A cubic foot of any gas may readily be compressed into half a foot; double the pressure will reduce it to a quarter of a foot; and when the pressure is removed, the gas returns to its original bulk. But no ordinary pressure produces any sensible compression on water or any other liquid. Hence gases have been denominated *elastic fluids*, and liquids *non-elastic*. It is on account of this difference that the mechanical properties of the two classes of fluids are treated of apart. The laws of liquids form the subject of Hydrostatics and Hydraulics—the former term (from two Greek words signifying *water* and to *stand*) embracing the doctrine of the equilibrium of liquids; the latter (from the Greek for *water* and a *pipe*), the doctrine of liquids in motion.

We have said that liquids cannot be sensibly compressed by any ordinary force; and this is so far true, that both in the theory of hydrostatics and in practice they are assumed to be perfectly incompressible. But the assumption is not absolutely correct. They are slightly compressible under great pressure. By sinking a vessel in the ocean to the depth of 6000 feet, where every square inch supports a weight of 2648 pounds, it is found that twenty cubic inches of water contained in the vessel are reduced to nineteen cubic inches, or the volume of water is diminished by one-twentieth. A pressure equal to that of the atmosphere, or fifteen pounds on the square inch, reduces a million cubic inches of water to about forty-five inches less.

HYDROSTATICS.

In treating of the mechanical properties of liquids, water, as the most common and important, is taken to represent the whole class. We have nothing to do here with the fact that water is composed of two gases—that belongs to chemistry. The atoms of oxygen and hydrogen having united in pairs to form compound atoms or molecules of water, the science of Hydrostatics depends on the way in which these compound molecules, or particles, join together to form a mass. It is obviously different from the way in which a heap of sand is composed. For one thing, the sand, however fine, may still be seen to be composed of separate solid grains, which, under the microscope, become real blocks of stone, while the molecules of water are quite invisible, and must be inconceivably minute. The particles of sand, again, move over one another, it is true, but with considerable friction or resistance, as is seen by their remaining standing up in a heap; the particles of water slide upon one another without the least apparent friction, and when not confined, spread out into a thin film. Another point of difference is, that the separate particles of sand have no cohesion among themselves; the cohesion among the molecules of water, though weak, is still sensible, as is seen in a drop hanging suspended at the end of a rod. A liquid differs from a solid, not so much in the force with which the particles of either resist separation, as in the force with which the particles of the solid resist changing their relative position. We may conceive two molecules of water, in the form of two minute balls, in contact; and when one of them is pushed, it slides round on the other, adhering to it as it moves. Two molecules of a solid resist this sliding motion, and if forced to change their points of contact, can no longer cohere; as if they only attracted each other by certain sides. It is this property that enables solids to retain a fixed shape; fluids have no shape, but what they receive from the containing vessel.

Not only have the particles of a liquid an attraction for one another—the attraction of *cohesion*—but there is an attraction between most liquids and solids; this is the cause of a liquid *wetting* a solid. The particles of one liquid, also, often adhere to those of another; and gases similarly adhere to liquids. This species of attraction is known as *adhesion*. The combined action of *adhesion* and *cohesion* gives rise to many interesting phenomena; among others, to *capillary* attraction and *osmose*, described among the general properties of matter under NATURAL PHILOSOPHY.

It is the perfect *mobility* of the particles of liquids that gives them the mechanical properties considered in Hydrostatics. The fundamental property may be thus stated: *When a pressure is exerted on any part of the surface of a liquid, that pressure is transmitted undiminished to all parts of the mass, and in all directions.* Most of the other propositions of hydrostatics are only different forms or direct consequences of this truth.

The proposition may be experimentally proved in a variety of ways. If, for instance, a bladder is filled with water, and tied, and then pressed down with one hand; the other hand, if applied to the bladder, will be pushed out with corresponding force, and that

whether resting on the top, the sides, or under. Suppose, again, a close box B filled with water, and having a tube inserted into the upper cover with a plug or piston *a*, an inch in area, fitting into it. If the piston *a* is now pressed down upon the water with a force equal to a pound-weight, the water, being unable to escape, will react upon the piston with the same force; but it obviously will not press more against *a* than against any other part of the box, therefore every square inch is pressed outward with the force of a pound. If, then, there is another tube inserted in any part of the box with a plug of the same area, as at *b*, it will require a force of a pound to keep this plug in its place. (We leave out of account at present the pressure upon *b* arising from the *weight* of the water in the box above it, and consider only the pressure propagated by the forcing down of the plug *a*.) However many plugs of the same size there were, each would be pressed out with the same force of a pound; and if there were a large plug of four times the area, as at *c*, it would be pressed out with a force of four pounds.

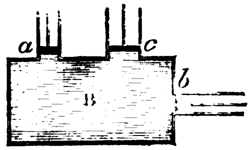


Fig. 1.

We have only, then, to enlarge the area of the piston *c* to obtain any multiplication of the force exerted at *a*. If the area of *c* is 1000 inches, that of *a* being one inch, a pressure of one pound on *a* becomes a pressure of 1000 pounds on *c*; and if we make the pressure on *a* one ton, that on *c* will be 1000 tons. This seemingly wonderful multiplication of power has received the name of the *hydrostatic paradox*. It is, however, nothing more than what takes place in the lever, when one pound on the long arm is made to balance 100 pounds on the short arm. The law of virtual velocities holds in the one case as well as in the other: when we think of the machine in motion, we see that what is gained in power, is lost in time. If the piston *a* descend one inch, it will raise the piston *c* only the one-thousandth part of an inch. It is on the principle now explained with regard to the two pistons *a* and *c*, that the very useful machine called *Bramah's* Press is constructed, as will be more fully described afterwards.

If the pressure we have supposed exerted on the piston *a* arose from a pound of water poured into the tube above it, it would continue the same though the piston were removed. The pound of water in the tube is then pressing with its whole weight on every square inch of the inner surface of the box—downwards, sidewise, and upwards—and, if the box is twenty inches each way, so as to have upwards of 2000 inches of surface, this one pound of water is tending to burst it with a force of about a ton. That this is no mere theory, may be proved without much difficulty, by fitting a long small tube, *b*, into the top of a cask, *a*, as represented in fig. 2. If the tube is only the twentieth of an inch in area, and is made long enough to contain a pound of water, it gives a bursting force of twenty pounds on every square inch of the inner surface—a strain which no ordinary cask could resist.

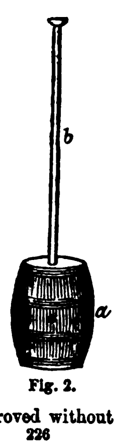


Fig. 2.

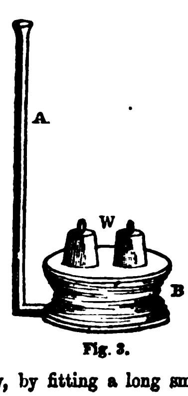


Fig. 3.

The apparatus called the *hydrostatic bellows* acts on the same principle (see fig. 3). It consists of two stout circular boards connected together by leather in the manner of a bellows B. The tube A is connected with the interior; and a person standing on the upper board, and pouring water into the tube, may lift himself up. If the area of the upper board is 1000 times that of the tube, an ounce of water in the tube will support 1000 ounces at W.

If we conceive a mountain having a cavity in its interior, as at B in fig. 4, without any outlet except a crevice, A, extending upwards to the surface; the rain descending and filling the crevice to a great height, might be sufficient to burst the mountain asunder.

Fig. 4.

PRESSURE OF WATER ARISING FROM ITS OWN WEIGHT.

Water has weight like solids, and this weight produces pressure, but the quality by which it transmits pressure in all directions makes its weight be felt in many respects differently from that of solids. Thus, suppose a cylindrical vessel filled with a piece of ice exactly fitting it; the whole weight of the ice will rest on the bottom, the sides being unaffected. But if the ice is now melted, the bottom will sustain the same weight as before, and the sides will at the same time be pressed outwards with a certain force. Any object immersed in water is also pressed or squeezed by the weight of the water. We have now to determine the amount of this pressure caused by the weight of water in various circumstances.

The pressure of water increases in intensity with the depth, without regard to the shape or size of the vessel containing it. Suppose the water in the two vessels represented in fig. 5 to be divided into layers of an inch deep. If the area of the tube C is one square inch, and that of the larger cylinder, A, ten inches, the top layer in the tube will contain a cubic inch of water, and that in the cylinder ten cubic inches. Now, these layers rest on the surfaces of the layers below them; the second layer in the tube sustains the weight of a cubic inch of water; that in the cylinder, ten cubic inches. But in the last case the weight is equally distributed over ten square inches of surface; in both cases, then, the pressure on a square inch of the upper surface of the second layer is the weight of a cubic inch of water, or about 252 grains. And this pressure is not merely downwards. The film of particles sustaining this weight react on the upper layer, pushing it upwards, and also push sidewise

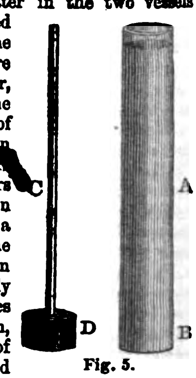


Fig. 5.

against each other and against the sides of the vessels, all with equal force. In like manner, each square inch of the surface of the second layer, in either vessel, has to bear the weight of two cubic inches of water, and the particles at that depth push upwards and laterally with corresponding intensity. The pressure thus increases with the depth equally in the narrow vessel and in the wide.

If we suppose the vessels to be each a foot deep, it is evident that on every square inch of the bottom of the cylinder there will rest a pile of twelve cubic inches (weighing about half a pound troy), and therefore the pressure on the whole bottom will be the weight of ten such columns. But from the shape of the other vessel, the lower part of which is enlarged, it is not so evident what the pressure on the bottom is. One thing is clear, that, on the square inch in the middle of the bottom immediately under the tube, there rests a column of twelve cubic inches. Now, there must be the same pressure among the particles of the water lying around the bottom of this column, as among its own particles, otherwise there would be a flow towards the part where the pressure was less. Throughout the whole of the enlarged space D, there is the same pressure as there is at the same level immediately under the tube. Therefore, if the enlarged part of the vessel is of the same width as the cylinder, having an area of ten square inches, the pressure on the whole bottom is equal to the weight of ten times twelve cubic inches of water, exactly as in the cylinder at B.

It thus appears that *the pressure on the horizontal bottom of a vessel is as the area of the bottom and the perpendicular height of the liquid*, and that without regard to the shape of the vessel.

Take the case of two vessels of equal capacity, and shaped as in figs. 6 and 7. In fig. 6, the bottom is pressed with the weight of the column of water ACDB. In fig. 7, the portion CD, equal to the whole base of the other, sustains an equal column; but from the law of liquids the same pressure is extended over the whole bottom. Now, if the diameter EF is three times the diameter CD, the larger bottom is nine times the area of the smaller. Therefore the pressure on the bottom of fig. 7 is nine times the pressure on that of fig. 6, although both vessels contain the same quantity of water. If the bottoms of the vessels were separate from the sides, and kept in their places by springs or weights, it could be shewn experimentally that such is the case.

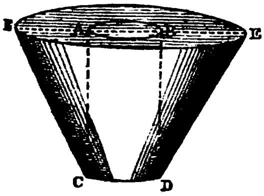


Fig. 6.

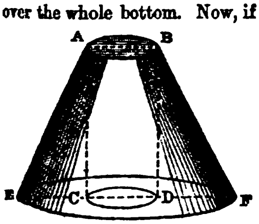


Fig. 7.

A strange consequence would seem to follow from this. If the two vessels in fig. 5 were placed on the opposite scales of a beam, the bottoms of both being equally pressed, it would seem as if they must balance each other. Similarly, we might expect fig. 7 to weigh nine times as much as fig. 6. But that such cannot be the case appears from the following considerations:—In the upright cylinder in fig. 5, the lateral pressure being directly horizontal, neither presses the sides down upon the bottom nor lifts them up; but with the irregular vessel it is different. Where the small tube C enters the wide part D—say two inches from the bottom—the pressure of the column is equal to ten cubic inches of water on the square inch; and as this pressure acts upwards as well as downwards, the horizontal cover of the wide part is pressed *upwards* with a force of ten cubic inches on the square inch. Its area, the tube being one inch, is nine inches, so that the whole upward pressure is 9×10 cubic inches. The cover being attached to the sides, and the sides to the bottom, a part of the pressure on the bottom is thus counteracted, and only the difference—the difference between 10×12 and 9×10—or thirty cubic inches of water—remains to weigh down the scale. The confined water is in this case like a person in a covered box who should place his shoulders against the top and press against the bottom with his feet; he would thus add nothing to the weight of the box beyond his own dead weight.

Pressure of Liquids on the Sides of Vessels.—We may arrive at a rule for calculating the amount of the lateral pressure of liquids by considering a vessel of the shape represented in the annexed figure. Dividing the depth into ten equal sections, representing feet, conceive the water composed of horizontal layers, each a foot thick. Then on a square inch of the surface of the second layer, adjoining the side, there rests a pile of twelve cubic inches pressing it with their weight. But liquids press sidewise as well as downwards; and therefore the pressure against the side, just where the first and second layers meet, is at the rate of the weight of twelve cubic inches on a square inch. At the second section, the pressure is evidently double, or that due to twenty-four inches, and so on to the bottom, where a square inch sustains the pressure of ten times twelve cubic inches of water. If, then, we take a vertical row of square inches, or—which is the same thing—of square feet, on the side of the vessel, they sustain pressures diminishing in intensity from the bottom to the top; and to get the amount of pressure on the whole, we must multiply the number of square feet by the *mean* pressure, which is at section 5, and amounts to the weight of five cubic feet on every square foot.

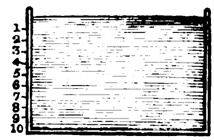


Fig. 8.

We may thus calculate the degree of lateral pressure in vessels having perpendicular sides *by first finding the number of square feet in the sides below the surface of the liquid, and then multiplying that by the number of feet in half the depth of the liquid.* The number of square feet in the sides is found by multiplying the number of feet in the circumference of the bottom by the number of feet in the depth of the liquid.

The above rule gives the pressure in cubic feet of water. It is easy to reduce this to weight by remembering that a cubic foot of water weighs very nearly 1000 ounces (strictly 997 ounces). *Example.*—Suppose a vat 24 feet deep from the surface of the liquid, and 40 feet in circumference. The area of the sides is $24 \times 40 = 960$; 960 multiplied by half the depth, or 12, gives 11,520 cubic feet of water; and 11,520 cubic feet of water weigh 11,520,000 ounces, or upwards of 320 tons—the bursting force which the hoops of the vat have to resist.

The same principle holds though the sides be not perpendicular, but sloping outwards or inwards. The rule is still—multiply the number of square feet in the side by half the perpendicular depth of the liquid; or rather, if the side is not rectangular, by the average depth of the liquid upon the side—that is, by the depth of the centre of gravity of the side.

It is easy to see that the pressure on the sides of a vessel may often, in this way, be greater than the whole weight of the liquid, according to the shape of the vessel. In a cubical box, in which any side is equal to the base, the pressure on one side is equal to half the weight of the contained water; and on all four sides it is just double the weight. When the area of the upright surface pressed upon is twice the area of the bottom, the lateral and perpendicular pressures are equal.

The circumstance of pressure increasing in proportion

to depth, makes it necessary to increase the breadth of embankments for dams and canals from the top downwards; also to increase the strength of the lower hoops of large vats, to prevent their bursting. It likewise teaches the propriety of making dams, ponds, canals, and vessels for liquids generally, as shallow as is consistent with convenience or their required purpose. In every case, it is important to recollect that the degree of pressure on the sides is irrespective of shape or size of the contents, and depends exclusively on the perpendicular depth of the liquid.

When the poet speaks of 'the *broad* ocean leaning against the land,' we are apt to think of the broadness as adding to the weight that the land has to sustain. But the pressure against a square foot of the shore of the broad Atlantic is no greater than against a foot of the shore opposite Dover, or a foot of the side of a canal, at the same depth. The pressure against the gates of a canal is the same whether the next lock is a mile or whether it is fifty yards off. It might be brought within a foot, or even a fraction of an inch, and the weight on the gate would remain unchanged so long as the depth was the same. This being the case, it is really no more difficult to embank the calm ocean than a small lake of the same depth; except for the violence of the waves, the same strength of dike would resist the weight in both cases.

When we consider that every five feet in depth gives a weight of about two pounds on the square inch, we see what an enormous compression bodies must suffer when sunk to great depths in the ocean. This of itself would put a limit to the depth at which fishes can live.

THE LEVEL SURFACE OF LIQUIDS.

A horizontal plane or horizontal line is one that is perpendicular to, or right across the direction of a plumb-line, or the direction of gravity. The surface of a mass of water, if not extensive, does not differ sensibly from such a plane. This follows from the properties of liquids above considered. Suppose a horizontal plane at any depth in a mass of liquid; if any part of the surface were heaped up, so as to stand higher above this level than other parts, there would be more pressure at the bottom of the column under that part than elsewhere in the same horizontal stratum, and a flow would take place till the higher column were of the same depth as the others. Or we might consider the particles at the surface of such a liquid heap as lying on an inclined plane, when their gravity would make them roll down to a lower position. It is only the imperfect mobility of sand that prevents it from assuming a perfectly level surface, as well as water.

It seems so natural that the surface of an unbroken mass of liquid should be all of one height, that we seldom think of it as requiring explanation. But when the surface of a liquid is not continuous, being contained in separate vessels with communication between them, it requires consideration and experience to convince us that the several parts of the surface must in all cases stand at the same level. A common tea-pot affords the most familiar illustration of this truth. Since pressure in a liquid depends exclusively on the depth, without regard to the shape or size of the mass, the pressure on a square inch at the level of communication is the same under A as under B; thus there is equilibrium. If an inch of additional water is put on the top at B, the pressure at the bottom is increased by that much, and a flow takes place along the line of communication till the whole again stand at the same height, the surfaces coinciding with a horizontal line AB.

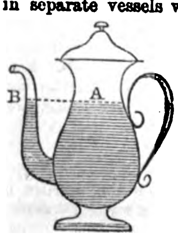


Fig. 9.

We have considered the surface of water as perfectly flat and straight; and a small surface is practically so. But in the case of extensive surfaces—such as that of the ocean or of a large lake—it becomes evident that the shape is round or spherical, partaking of the general form of the earth. By considering the figure below, we shall see that a liquid must assume this shape. The curve ETS represents a portion of the earth's surface, the centre being C. At any point T, the plumb-line PT, or the direction of gravity, is towards the centre. A line perpendicular to this is a horizontal line; and if such a line, or a flat plane, were extended far enough, it would rise up from the surface of the earth like TL, forming what is called a *tangent*. If particles of water were lying on such a plane at T, the force of gravity would press them right against the plane, and they would have no tendency to flow to either side. But water at L is differently circumstanced. Gravity does not press it right against the plane, but slanting, towards C, and thus gives it a motion along the plane to T. The water is, in fact, on an inclined plane all the way till it get to T, and will flow in that direction till it heap up the surface into a round shape, where every point is equally distant from the earth's centre.

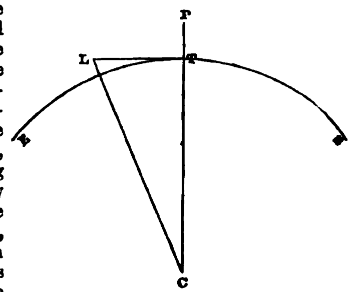


Fig. 10.

It is only when a sheet of water is stretched out to an extent of several miles that the convexity becomes conspicuous. It is very perceptible on the ocean when a ship is approaching on the horizon; first the masts and sails of the ship are seen, and lastly, the hull. The convexity of the land is not so conspicuous, in consequence of the many risings and fallings in the surface. It is only in extensive plains that the roundness can be perceived in the same manner as at sea.

The amount of the earth's convexity can be calculated exactly. It is very nearly eight inches in each mile; that is, if TL (fig. 10) is a mile long, the point L will be eight inches above the surface.

In constructing canals and railways, allowance must be made for the convexity of the earth; for the channel of a canal, or a line of level railway, does not form a straight line, but a curve; it is not a part of the tangent or *apparent level* TL, but of the curve TE, which is the *natural or dead level*. The instrument by which levels are determined is called a *spirit-level*. It consists of a glass cylinder *ac*, filled with spirits all except a small space. It is placed for protection in a wooden case, the bottom of which is exactly parallel with the sides of the tube. If the instrument is laid on the upper surface of a stone slab or a beam, and if one end of the beam is higher than the other, the liquid in the tube will seek the lowest position, and the air-bubble will move towards the higher end; when the bubble rests in the middle, as at *b*, the surface is horizontal or level. To ascertain levels at a distance, the spirit-level is fixed below a small telescope, the tube of the telescope and the glass tube being made exactly parallel. The telescope being fixed on a stand, is adjusted by screws until the air-bubble of the spirit-level stands exactly in the middle, and is thus made perfectly horizontal. A pole being now set up at the spot where the level is to be found, the level telescope is directed to it, and the point of the pole which appears in the centre of view is in a horizontal

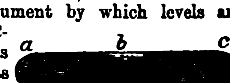


Fig. 11.

line with the eye. If the distance is short, this point may be considered as the level; but if the pole is as far as a mile off, the natural level at which water would stand, if there were a sheet of it all the way, will be eight inches below.

SOLIDS IMMERSED IN LIQUIDS.

When a solid is immersed in a liquid, it displaces exactly its own bulk of the liquid. This requires no demonstration; as soon as we conceive clearly what is meant, the truth of the proposition is self-evident. Of course it is only of solids that are neither melted nor penetrated by the liquid that the proposition holds good.

If a cubic inch of wood or of a metal is wholly immersed in a vessel previously full of water, the liquid that occupied the space where the solid now is, must overflow; or, if the vessel was not full, the level of the liquid must rise. This affords a ready means of measuring solids, even the most irregular in shape. To ascertain what bulk of solid metal there is in a gold chain: have a cylindrical vessel with a base of known area—say a square inch—filled to a certain height with water; drop in the chain, and note the rise of the liquid. If it rise an inch, the chain contains a solid inch of gold, and so for any fraction of an inch. Archimedes is said to have been the first to think of measuring solid bodies in this way, and to have applied it in detecting the adulteration of a gold crown.

Every one must have experienced that a heavy body held in the hand becomes lighter when it is immersed in a liquid. We have now to consider how this loss of weight arises, and what is its amount.

Let a solid AB occupy a space within a mass of water.

Fig. 12.

Conceive first, that the space were again occupied by a body of water separated from the rest by an imaginary film; this water will clearly remain suspended like any other portion of the mass. Now, as its weight is pressing it downwards, there must be an equal force acting upon it upwards. That force arises from the pressure of the surrounding liquid, which is acting upon it in all directions, upwards, downwards, and laterally. Some parts of this pressure counteract other parts; but the under surface being at a greater depth than the upper, there remains a balance of upward pressure. This balance or result must be exactly equal to the weight of the conceived isolated body, and must also act on the centre of gravity of that body *g*, otherwise it could not keep it at rest. The upward pressure, then, on any separate portion AB, say a cubic foot, within a mass of liquid, is equal to the weight of that portion. If we now suppose the mass of water, AB, to become solid ice without change of bulk, the same pressure will act upon it as before; and if we further conceive the cubic foot of ice to become a cubic foot of gold, the upward pressure upon it will remain the same—namely, the weight of a cubic foot of water, or the weight of the water it displaces. To this extent the water supports it, and renders it lighter.

It appears, then, that *a solid body in a liquid loses as much weight as an equal bulk of the liquid weighs.* If a cubic foot of the liquid and of the solid have equal weights, the solid will lose all its weight, or will remain in the liquid wherever it is put; if a cubic foot of the liquid weigh more than one of the solid, the solid will not only lose all its weight, but will rise up, and that with a force equal to the difference; if a cubic foot of the liquid weigh less than one of the solid, the solid will lose weight, but will still sink.

When a solid swims, or rises and *floats* on the surface of a liquid, the next problem of hydrostatics is to determine how much of it will be below the surface. We have already seen that any solid in a liquid is pressed upward with a force equal to the weight of the water whose room it occupies. Now, a floating body must be pressed up with a force equal to its own weight, otherwise it would sink lower; hence, when at rest, it must displace its own weight of the water. A solid, as AB in fig. 13, sinks until the space occupied by the part B immersed would contain an amount of water equal in weight to the whole solid AB.

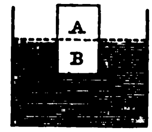


Fig. 13.

By measuring how many cubic feet of water a floating body, such as a ship, displaces, we can thus know its weight, by allowing 1000 ounces for every cubic foot. If we knew previously the weight of the ship and rigging, the difference would give the weight of the cargo. As the buoyancy of a body thus depends on the relation between its weight and the weight of an equal bulk of the liquid, the same body will be more or less buoyant, according to the density of the liquid in which it is immersed. A piece of wood that sinks a foot in water, will sink barely an inch in mercury. Mercury buoys up even iron. Sea-water is denser than fresh water, in the proportion of 1026 to 1000. A ship, then, that carries 1026 tons on the sea, would carry only 1000 tons on a fresh-water lake.

The human body has almost the same weight as an equal bulk of water. When the lungs are full of air, it is slightly lighter, and will float with a bulk of about half the head above water. A person, then, that cannot swim, but has presence of mind to lie flat on the back, with the back part of the head submerged, may, by keeping the lungs full, continue to float with the face above water; but if any other part of the body, as a hand, is raised above the surface, the whole head goes immediately under. Swimmers, by the action of hands and feet against the water, keep the whole head, and often more, above the surface. A body which would sink of itself, is buoyed up by attaching to it a lighter body; the bulk is thus increased without proportionally increasing the weight. This is the principle of life-preservers of all kinds. The most common are those which consist of pieces of cork, or other very light material, attached to the upper part of the body. But air-tight bags are preferable, as they may be said scarcely to encumber the body when empty, and, as danger approaches, they can be inflated with ease by being blown into. Life-boats have large quantities of cork in their structure, and also air-tight vessels made of thin metallic plates; so that, even when the boat is filled with water, a considerable portion of it still floats above the general surface. The bodies of some animals, as sea-fowl, and many other species of birds, are considerably lighter than water. The feathers with which they are covered add very much to their buoyancy. Fishes are enabled to alter their buoyancy by means of an air-bag, which they can inflate at pleasure by an apparatus for generating gases.*

The heaviest substances may be made to float by shaping them so as to make them displace more than their own weight of water. A flat plate of iron sinks; the same plate, made concave like a cup or boat, floats. By making the sides of an iron vessel double, with a considerable air-tight space between the plates, the vessel would be prevented from altogether sinking, even when filled with water.

* The bodies of most fishes are nearly of the specific gravity of water, and therefore, if living in it without making exertion, they neither sink nor swim. When this subject was less understood, many persons believed that fishes had no weight in water; and it is related as a joke at the expense of the philosophers, that a king having once proposed as a task to his men of science to explain this extraordinary fact, many profound disquisitions came forth, but not one of the competitors thought of trying what really was the fact. At last a simple man [who doubted the fact] balanced a vessel of water in scales, and on putting a fish into it, shewed a scale preponderating, just as much as if the fish had been weighed alone.—*Arnott's Elements of Physics.*

The buoyant property of liquids is independent of their depth or expanse, if there be only enough to surround the object. A few pounds of water might be made to bear up a body of a ton-weight; a ship floats as high in a small dock as in the ocean.

The *stability* of a floating body depends upon the relative position of two points—the centre of gravity of the body itself, and the centre of gravity of the water displaced, which is called the *centre of buoyancy*. Since the downward pressure is concentrated in the centre of

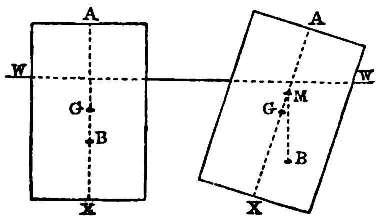


Fig. 14.

gravity G of the floating body (fig. 14), and the upward at B, the centre of gravity of the space from which the water is displaced, there will be equilibrium when the two are in the same vertical line. When the body is moved to one side, B and G are no longer vertical; the line of upward pressure does not pass through the centre of gravity, but meets the axis of the body at a point M, called the *metacentre*, or *beyond the centre*. This point is nearly constant in position for small inclinations on either side. If it lie above the centre of gravity, it is evident that the upward pressure of buoyancy will tend to turn the body about its centre of gravity back towards its original position; if it is below, the body is pushed further and further from that position, and is thus upset. It is thus an object to have the centre of gravity of a vessel as low as possible, in order to secure its stability. With this view, heavy materials, in the shape of ballast, are placed in the bottom, and heavy cargo is stowed low in the hold.

SPECIFIC GRAVITY.

If a lump of sulphur is weighed in air, and found to be two ounces, when weighed in water it will be found to weigh only one ounce. Now, as we know that the weight which a body loses in water is exactly the weight of an equal bulk of water, we infer that a body of water equal in size to the lump of sulphur weighs an ounce. Bulk for bulk, then, sulphur is twice as heavy as water, or their weights are as 2 to 1. In the same way, if a piece of cast iron, of say thirty-five pounds' weight, is weighed in water, it will lose about five pounds; cast iron, then, is about seven times as heavy as water, or their weights are as 7 to 1. By thus referring substances to water as a standard, we get a convenient view of their comparative densities, or *specific gravities*, as the term is. The specific gravity of a body, then, is its weight compared with that of water, which is generally expressed by 1. Thus, gold is found to weigh about $19\frac{1}{3}$ times as much as an equal bulk of water; its specific gravity therefore is $19\frac{1}{3}$. Others take 1000 as the specific gravity of water; and by this scale that of gold is 19,325.

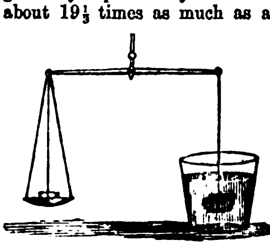


Fig. 15.

The apparatus used in such experiments is called the hydrostatic-balance, a simple form of which is represented in fig. 15. One application of it is to detect whether gold is alloyed. Knowing how much weight a pound of pure gold should lose in water, if an object said to be gold is found to lose more than the right proportion, it is a proof that it is adulterated with some more bulky metal.

In ascertaining the specific gravity of solids that are lighter than water, and of such as melt in it, various expedients must be had recourse to; but the principle in all is the same. To determine the specific gravity of a liquid, take a known weight of any solid that does not melt in the liquid or in water, and that is heavier than either, and observe its loss when weighed in water, and also when weighed in the liquid. These losses are the weights of equal bulks of water and of the liquid, and therefore express their comparative densities; and if the loss in the liquid is divided by that in water, the quotient will be the specific gravity of the liquid, that of water being 1. Thus, a cubic inch of lead loses 253 grains when weighed in water, and only 209 grains when weighed in rectified spirit; therefore a cubic inch of rectified spirit weighs 209 grains, an equal bulk of water weighing 252; and so the specific gravity of water is about a fourth greater than that of the spirit.

Instruments for readily indicating the specific gravities of liquids are called *hydrometers*. The name is derived from two Greek words, signifying *measure of water;* but it is of course used for ascertaining the density of all kinds of liquids. There are various kinds of hydrometers. The illustration here given shews one of great delicacy and exactness. It consists (fig. 16) of a ball of glass *b*, about three inches diameter, with another *c*, joined to it, and opening into it, of one inch diameter, and a brass neck *d*, into which is screwed a wire *ae*, divided into inches and tenths of an inch, about ten inches long, and one-fortieth of an inch in diameter. The whole weight of the instrument is 4000 grains when loaded with small weights, such as shot, in the lower ball *c*. When plunged into water in the jar, this instrument is found to sink an inch if a single grain be laid upon the top *a*; hence a tenth of a grain sinks it a tenth of an inch. So great is the delicacy of this hydrometer, that a difference in specific gravity of one part in 40,000 can be detected. To find the gravity of fluids lighter or heavier than the standard of comparison, the shot in the ball can be altered as required. As heat expands liquids, rendering them specifically lighter, great attention must be paid to the temperature of those experimented upon, as otherwise wrong results will be obtained. Spirits, for instance, will be apparently stronger in hot weather than in cold.

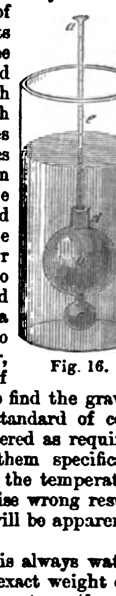


Fig. 16.

For solids and liquids, the standard is always water; it is therefore important to know the exact weight of a certain bulk of water at a fixed temperature (for the bulk alters with the temperature). Now, it is found that at the temperature of 62°, a cubic inch of distilled water weighs 252·458 grains; therefore a cubic foot weighs 997 ounces avoirdupois, or very nearly 1000 ounces. If, then, gold is nineteen times heavier than water, a cubic foot of gold will weigh 19,000 ounces; and so of any other substance.

The heaviest substance known is platinum, whose specific gravity is 22. There are metals, again, lighter than water, as potassium and sodium. One liquid, mercury, has a specific gravity of $13\frac{1}{2}$; ether is only 0·715. The lightest substance known is hydrogen gas. The standard of comparison for gases is atmospheric air, which is about 800 times lighter than water. Its specific gravity is taken at 1000. Hydrogen is fourteen times lighter than air; while carbonic acid and chlorine are more than twice as heavy as air. The vapour of iodine is eight times the weight of atmospheric air.

TABLE OF SPECIFIC GRAVITIES OF SOME BODIES.

SOLIDS.

Platinum, coined,	22·100	Porcelain, Dresden,	2·493
" , wire,	19·267	" , China,	2·384
Gold, coined,	19·325	Sulphur, natural,	2·033
Lead, fused,	11·352	Ivory,	1·917
Silver,	10·474	Anthracite,	1·800
Copper, hammered,	8·878	Wax, white,	0·969
" , fused,	7·788	Sodium,	0·972
Brass,	8·395	Potassium,	0·865
Steel,	7·816	Ebony,	1·226
Iron, wrought,	7·788	Oak, old,	1·170
" , cast,	7·207	Box,	1·330
Tin,	7·291	Beech, green,	0·982
Heavy Spar,	4·426	" , dry,	0·590
Diamond,	3·520	Pine, green,	0·890
Flint Glass, English,	3·373	" , dry,	0·555
Plate Glass,	2·370	Mahogany,	1·060
Marble,	2·837	Poplar,	0·383
Rock Crystal,	2·683	Cork,	0·240

LIQUIDS (AT 32°).

Distilled Water,	1·000	Wine, Rhenish,	0·999
Mercury,	13·598	Oils—Citron,	0·852
Sulphuric Acid,	1·848	" Linseed,	0·953
Milk,	1·030	" Olive,	0·915
Sea Water,	1·026	" Turpentine,	0·872
Wines—Claret,	0·994	Alcohol, absolute,	0·793
" Champagne,	0·998	Proof Spirit,	0·920
" Malaga,	1·022	Sulphuric Ether,	0·715

HYDRAULICS.

We are now to consider the phenomena of water in motion, and acting as a moving power.

FLOW OF WATER THROUGH APERTURES AND PIPES.

If three apertures, A, B, C, are made at different heights in the side of a vessel (fig. 17) filled with water, the liquid will pour out with greater impetuosity from B than from A, and from C than from B. The velocity does not increase in the simple ratio of the depth. The exact law of dependence is known as the theorem of Torricelli, and is to this effect:—'Particles of fluid, on issuing from an aperture, possess the same degree of velocity as if they had fallen freely, *in vacuo*, from a height equal to the distance of the surface of the fluid above the centre of the aperture.' The jet from B, for instance, has the same velocity as if the particles composing it had fallen in vacuo from H to B. Now, the velocity acquired by a body in falling is as the time of the fall; but the space fallen through being as the *square* of the time (see NATURAL PHILOSOPHY), it follows that the velocity acquired is as the square root of the space fallen through. In the first second, a body falls 16 feet, and acquires a velocity of 32 feet. If C, then, is 16 feet below H, a jet from C flows at the rate of 32 feet; and if A is at a depth of 4 feet, or one-fourth that of C, the velocity of the jet at A will be half the velocity of that at C, or 16 feet. In general, to find the velocity for any given height, multiply the square root of the height by $\frac{16}{2}$, or 8. The height of the water in the reservoir above the issue is technically called the 'head.'

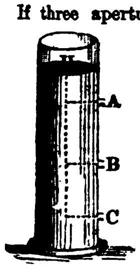


Fig. 17.

When, by means of the area of the opening and the velocity thus determined, we calculate the number of cubic feet or of gallons that *ought* to flow out in a given time, and then measure the quantity that actually does flow, we find that the actual flow falls short of the theoretical by at least a third. In fact, it is only the central part of the jet, which approaches the opening directly, that has the velocity above stated. The outer particles approach from all sides, with less velocity; they jostle and crowd one another, as it were, and thus the flow is retarded. In consequence of this want of uniformity in velocity and direction among the component layers of the jet, as they enter the orifice, there takes place what is called a 'contraction of the vein' (*vena contracta*); that is, the jet, after leaving the orifice, tapers, and becomes narrower. The greatest contraction is at a distance from the orifice equal to half its diameter; and there the section of the stream is about two-thirds the area of the opening.

It has as yet been supposed that the issue was by means of a simple opening or hole in the side of the vessel; but if the flow takes place through a short tube, the rate of discharge is remarkably affected. Through a simple opening, the actual discharge is only about 64 per cent. of the theoretical; through a cylindrical conducting-tube, or *adjutage*, as it is called, of like diameter, and whose length is four times its diameter, the discharge is 84 per cent. The effect is still greater if the discharge-tube is made conical both ways, first contracting like the contracted vein, and then widening. The effect of a conducting-tube in increasing the discharge is accounted for by the adhesion of the water to its sides, which widens out the column to a greater area than it would naturally have. It has thus a tendency to form a vacuum in the tube, which acts like suction on the water in the reservoir, and increases the quantity discharged.

The flow is more free if the orifice is in the bottom of the vessel, than in the side on a level with the bottom. If the discharge-tube is made to project inwards beyond the thickness of the walls of the vessel, the velocity is much impeded, owing to the opposing currents produced by the water approaching the opening.

Pipes.—The pressure and velocity with which water enters a conduit-pipe become more and more reduced by friction as it proceeds. The rate of reduction depends upon the diameter of the tube, its length, the bendings it undergoes, &c. The resistance to the flow of water in pipes does not arise properly from friction, as understood of solids, but from the adhesion of the water to the sides of the pipe, and from the cohesion of the watery particles among themselves; it makes little difference, therefore, whether an earthenware pipe, for instance, be glazed or not. Large projections form an obstacle; but mere roughness of surface is filled up by an adhering film of water, which is as good as a glaze. The resistance increases greatly with the narrowness of the pipes. Engineers have formulæ, deduced in great part from experiment, for calculating the discharge through pipes of given length and diameter, and with a given head; but the subject is too complicated for introduction here.

The flow of water through a pipe, when regulated by valves, is more or less impeded according to the form of valve used. A valve like the throttle-valve of a steam-engine (see STEAM-ENGINE), causes a double contraction, the water dividing to form two currents, one on each side of the valve; a conical valve, like that of a safety-valve, causes a like contraction. The best form of valve is the ball-valve with an aperture through it; by turning it round in its seat, the aperture is closed or opened.

Rivers.—The effects of friction between liquids and solids are nowhere so conspicuous as in the flowing of rivers. The natural tendency in the water to descend at a certain speed, is checked by friction, by bends in the course of the stream, and by projections on the banks and bottom. From these causes, the water in a river flows with different velocities at different parts in any vertical section across the current. It flows at a slower rate of speed at and near the bottom than at the surface, and also slower at the sides than at the middle. To get the mean velocity of a river or other stream, find first the surface velocity at the central part of the stream, by observing the rate in feet per minute at which a floating body is carried down. The float should be such as barely to reach the surface, so as not to be affected by the wind. If, from the square root of this surface velocity, we substract one, and then square the remainder, we get the bottom velocity. Half the sum of the surface and bottom velocities then gives the mean velocity;

and if this is multiplied by the area in feet of the cross-section of the stream, the product is the discharge in cubic feet per minute.

The abrasion of the banks and bottom of a canal or river depends upon the velocity. A velocity of 30 feet per minute will not disturb clay with sand and stones; one of 40 feet will sweep along coarse sand; of 60, fine gravel; of 120, rounded pebbles; and of 180, angular stones. The action on the banks is much lessened by making them sloping or shelving. Oblique currents in rivers or canals are caused by the presence of obstructions in the water-way, as rocks or stones. The water striking against these is deflected, and thrown against the bank opposite; hence those parts of the sides are much abraded. It is this unequal wearing away of the banks of rivers that gives them their serpentine character; which is most observable in flat countries, as, where the velocity of the current is considerable, it overcomes comparatively small impediments, and dashes forward in a straight course.

Resistance of Water to Bodies moving through it.—This is greatly affected by the shape of the body, which ought to have all its surfaces oblique to the direction of the motion. Hence ships, to sail well, must present sharp angles both at bows and stern. The best form in all respects for ships is still a disputed point, though it seems to be agreed that swift-swimming fish present the nearest approach to the true model.

The resistance offered to a moving body in water is as the square of the velocity; thus, with a double rate of speed, the resistance is four times. This is easily explained:—A vessel moving at the rate of one mile per hour displaces a certain quantity of water, and with a certain velocity; if it move twice as fast, it of course displaces twice as many particles in the same time, and requires to be moved by twice the force on that account; but it also displaces every particle with a double velocity, and requires another doubling of the power on this account; the power thus twice doubled becomes a power of four. When the body is moved with a speed of three or four, a force of nine or sixteen is wanted; and so on. Thus the resistance increases as the square of the speed.

This law is of great importance in practice. For instance, in steam-navigation, if an engine of fifty horse-power impel a vessel at the rate of seven miles an hour, it would require two of the same power to drive her ten miles an hour, and three such to drive her twelve miles an hour; hence the enormous expense of fuel attending the gaining of a high velocity.

The resistance offered to a floating vessel is greater in a canal than in a wide river or the sea. The water before the bow rises higher than the mean level, forming an incline from this to the stern; the narrower the canal, the greater the angle of this incline.

Waves.—Waves are the risings and fallings of the water, caused by some power, such as the blowing of the wind. The power, whatever it happen to be, communicates a force to the mass of liquid, and a series of undulations is the consequence.

These undulations or waves exhibit the transmission of the communicated force. The force does not advance or alter the lateral position of the water at any given point; it only alters the water in its vertical position, or in relation to its depth. When, therefore, waves advance, the water does not advance with them: the water but rises and falls, and assumes the figure of undulations on its surface. When the undulations approach a shallow shore, the water then acquires a progressive motion; and by friction on the bottom, or impulsion against the shore, the communicated force is exhausted. The shaking of a carpet affords an exact representation of the action of waves or undulations.

Waves are comparatively superficial; they seldom rise to a height of more than twelve feet above the level of calm water, and make an equal descent beneath, making altogether a difference of level of twenty-four feet: at eight or ten feet below the intervening hollow or trough of the waves, the water is tranquil. Waves 'mountains high' is only a figure of speech.

For motion in liquids produced by difference of temperature, see HEATING AND VENTILATION.

HYDRAULIC MACHINES.

Inverted Syphon.—The tendency in a liquid to find its level, furnishes, by means of a bent tube, one of the simplest and most useful of all hydraulic machines.

Fig. 18.

Its application is illustrated in fig. 18. A pipe is represented proceeding from a lake on the top of a hill down into a valley, and thence supplying a house situated on the opposite rising-ground. This contrivance supersedes the necessity of an aqueduct. From the pipe, in its passage across the valley, a small tube is carried to supply an ornamental fountain or jet d'eau. The water spouts from this jet d'eau with a force corresponding to the height of the lake above.

Water-meter.—The extended use of the 'constant system' of water-supply to houses, &c., has necessitated some means by which the quantity given can be registered, just as gas is measured when supplied to houses. Not only for this, but for a variety of purposes in the arts, is a good water-meter desiderated. It is impossible, under our present head, to give even a slight sketch of the numerous machines of this kind which have been introduced during the last few years. A very successful kind, which has been introduced to a large extent in Manchester and elsewhere, is that known as Taylor's patent.

A novel, and, as it appears, an efficient water-meter, has recently been introduced at the Salford Waterworks: in its arrangement, it differs from all others hitherto introduced.

The hydraulic-ram is a simple and conveniently applied mechanism, by which the momentum or weight of falling water can be made available for raising a portion of itself to a considerable height. In the figure annexed, the pipe *a* is that which leads the water from the source or spring, which might otherwise be allowed to run to waste, to the pipe *b*; at the end of this a valve, *e*, is situated, opening downwards and so weighted that it is capable of falling by its own weight, against the pressure of the column or head of water, when not in motion. Suppose the valve has fallen, and allowed a flow to take place along the tube; the water soon acquires momentum sufficient to force up the valve. This stops the flow, destroys the momentum, and leaves the valve again to fall. There thus takes place a succession of openings and shuttings of the valve; and at each shutting, the arrest of the momentum of the current causes a shock throughout the tube, which forces up another valve at *f*, opening

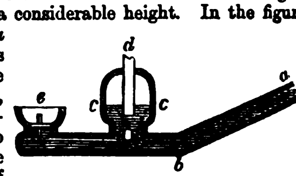


Fig. 19.

into an air-vessel *cc*, and injects a quantity of water into it. A tube, *d*, enters this air-vessel, and a stream of water is propelled up it, on the principle of the fire-engine (see fig. 31). The higher the source is above the valve *e*, the higher will the water be raised. The proportion of water lost by flowing through the valve *e*, to that sent up the pipe *d*, is very considerable; but from the continuous action of the mechanism, a large supply is soon obtained. In well-constructed rams, the mechanical effect obtained should be from 65 to 75 per cent. of the force supplied. For raising comparatively small quantities of water, such as for single houses, farm-yards, &c., the ram is the most superior mechanism yet introduced. The concussion, and consequent deterioration of the valves, places a limit to the use of this mechanism when applied to raise large quantities.

Bramah's Press.—The principle of the hydrostatic paradox (see p. 226) is turned to account in what is termed the hydraulic-press, invented by Bramah, in which a force-pump is used. In fig. 20, we give an

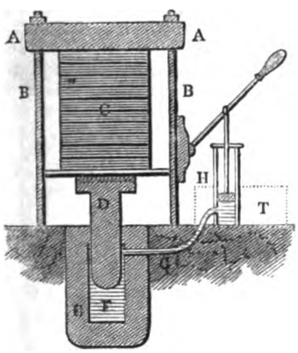


Fig. 20.

illustration of the arrangement used. B, B are pillars supporting the entablature AA, E the cylinder into which the piston D works; the water is passed into the cavity of the cylinder F, and forces up the piston and its table, thus pressing the bales, books, &c., C, with great force against the entablature AA. The water is forced from the tank or cistern T, by the force-pump H, through the pipe G, into the interior of the cylinder. The whole arrangements here shewn are of the simplest nature, the complicated mechanism adopted in practice not requiring to be introduced for our purposes.

The power of the hydraulic-press is readily calculated. Suppose that the pump has only one-thousandth of the area of F, and that, by means of its lever handle, the piston of the pump is pressed down with a force of 500 pounds, the piston of the barrel will rise with a force of one thousand times 500 pounds, or more than 200 tons. The rise, however, will be slow in proportion to the gain of power.

Water-power—Impact Wheels.—In using the impulse of water to act upon the various forms of water-wheels, the theoretical effect obtained is that which is expressed by multiplying the head of water, or the height from which it falls, by the weight of the water discharged in one minute. In practice, many modifying circumstances tend to reduce this effect materially; a considerable portion of the power being lost by friction, the distance of the wheel from the 'gate,' and numerous other causes.

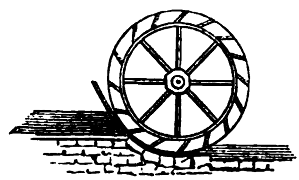


Fig. 21.

The simplest form of water-wheel is that known as the undershot, illustrated in fig. 21; it is only used in cases where the fall of water is low, or a high velocity is to be imparted to a small wheel. The gate should deliver the water as close to the wheel as possible; and the contraction of the flowing vein should be directed to the centre of the paddle. The channel in which the wheel works, should be only wide enough to admit of its free working. When performing the greatest amount of labour, the velocity of an undershot wheel is half that of the water in the channel—the point measuring the velocity of the wheel being taken at the centres of the paddles. The labour performed decreases as this velocity is increased; wheels of twenty feet diameter, if well constructed, may give as much as 33 per cent. of the power of the stream; smaller wheels will not give more than 25 per cent. In any case, however perfectly arranged, this form can never give more than one-half of the power. Where undershot wheels act in wide streams, the paddles are inclined to the diameter; the water rises upon them, and acts by its weight as well as impulse: if this inclination is 30°, the greatest effect is obtained.

Wheels with curved buckets are much more effective than those with radial paddles. Curved buckets should be used where the fall of water exceeds twelve feet, the water being introduced to the wheel a little below the highest point. Wheels thus used are termed overshot; a form is illustrated in fig. 22. When this laying of the water at the highest point is not practicable, it is

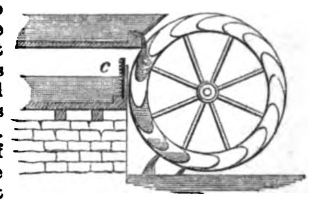


Fig. 22.

introduced at a lower point, as at *c*; the wheel thus arranged is sometimes termed a breast-wheel, when open buckets or paddles are used. Breast-wheels thus constructed are not economical, and are rarely used. In wheels such as the last figure illustrates, the water should be introduced so as to fall directly on the bottom of the buckets, not touching the backs. The speed of the circumference of the wheel should be a little less than half the height of free descent of bodies in the first second—that is, eight feet. The loss of power is increased by the buckets freeing themselves of water too soon, as well as too late; in the latter case, the wheel has to lift a certain weight of water needlessly. Where water is scarce, a slow-moving wheel and a strongly curved bucket will be found most advantageous. Curved buckets are not adapted for undershot wheels. In overshot wheels, the higher they receive the water, the slower the wheel moves, and the more curved the buckets may be, care being taken to allow the air to escape. This has been effected in the form of ventilating bucket introduced by Fairbairn. The amount of labour performed by overshot wheels varies from 10 to 65 per cent. of the power of water imparted.

Reaction from the Efflux of Fluids.—When a vessel filled with water has no outlet, the outward pressure on the sides has no tendency to push the vessel out of its place, because the pressure on any spot is counteracted by an exactly equal pressure on some other spot. But when an opening is made, as at A, B, or C (fig. 17), the pressure is less on that side of the vessel than on the other, and if the vessel were standing on a piece of wood floating on water, it would be seen to move in a direction opposite to the jet. A jet of air or steam has a similar effect to one of water. A tea-kettle mounted on wheels, with a spirit-lamp below it to make it boil, retreats from the current of steam that issues from the spout. This phenomenon is similar to the recoil of a musket, and may be considered as an instance of the law of reaction.

It is on this principle that water is made to act as

a moving power in what are called reaction wheels. Of this nature are the machines known as Barker's Mills. In the accompanying diagram (fig. 23), the apparatus consists of a vertical tube AB, moving freely on a pivot C, and receiving a supply of water from a stream D. This water is discharged by two opposite horizontal arms *e*, *e'*, the jets issuing in contrary directions, and by their reaction causing a rapid rotatory motion of the whole machine. The most approved form of reaction or centrifugal wheel is Fourneyron's Turbine, for a description of which we must refer to practical treatises on hydraulics. One drawback in horizontal wheels, or turbines generally, is the weight with which the mass of water presses on the pivot of the upright axle, thus causing great friction. This is obviated in some turbines by making the water enter the wheel from below, as represented in fig. 24;

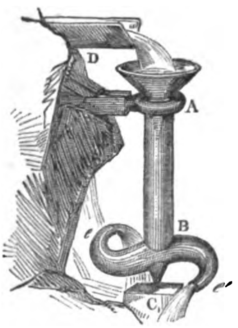


Fig. 23.

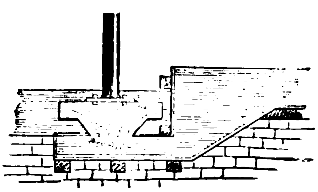


Fig. 24.

the greater part of the weight of the machine is thus supported by the water.

PNEUMATICS.

Pneumatics, from the Greek word *pneuma*, 'breath,' or 'air,' is that branch of science which treats of the weight, pressure, motion, and other mechanical effects of aëriform bodies. Modern science has made us acquainted with a number of distinct *airs*, besides common air; these are now usually called *gases*, and the name *air* is confined to the fluid composing our atmosphere. This itself is not a simple substance; it is a mixture of two distinct gases, oxygen and nitrogen. It belongs to Chemistry to explain the different natures of these two; it is only with the mechanical effects that we have at present to do, and in this respect the mixture acts as if it were a simple gas.

Aëriform fluids differ from one another in weight as well as liquids do (see p. 230). But, except as to specific gravity, the properties of air treated of in pneumatics are true of aëriform fluids generally. It is only the equilibrium of air that will be considered in this place; the phenomena of air in motion fall more conveniently under METEOROLOGY, VENTILATION, &c.

An *atmosphere* of air surrounds the globe like a continuous ocean, many miles in height. Air in small quantity appears *colourless*, owing to its extreme rarity; but when we look through a considerable depth of it, it is seen to be really blue. Hence the peculiar tint of the sky, and the blue colour of distant mountains. The blue is purer and brighter the less vapour is mixed with it. Were it not for the atmosphere, the heavens would appear as a perfectly black vault; and on very high mountains, where the greater part of the air is below, they are said to approach to black.

WEIGHT OF AIR.

The idea of air as a material fluid possessing weight and exerting pressure on everything immersed in it, is modern. The ancients thought of it as essentially *light*, or without weight, and as wanting generally the characteristics of matter; and they used the same words for 'breath,' 'air,' as for 'spirit,' 'life.' Yet it really possesses all the properties of matter, as surely as water does. A portion of it may be much compressed, indeed, but cannot be squeezed to nothing; it still occupies space, and is therefore *impenetrable* (see NATURAL PHILOSOPHY). It also resists sensibly a flat body, such as a fan moving through it; and when itself in motion, as in a strong wind, it is felt to have a powerful momentum or moving force.

With regard to the *weight* of air, nothing in the history of science is more remarkable than that men should have lived so long subject to the great pressure which this weight occasions, without discovering it. The fact is, that air acts so little on the senses, that it does not make us aware directly of its existence. The effects produced by its weight were therefore attributed to other causes. The facts, for instance, that go by the name of *suction*, are all owing to the pressure of the atmosphere. But when water was seen to rush up a pipe from which the air was withdrawn, it was explained by saying that 'nature abhors a vacuum,' that is, an empty space. This explanation continued to satisfy philosophers till the middle of the seventeenth century. Some mechanicians near Florence, having to construct a pump of unusual length, found, to their surprise, that the water refused to rise higher than thirty-two feet. This led to the conjecture that the weight of the atmosphere was the cause of water rising in the pump, and Torricelli, the pupil of Galileo, confirmed the conjecture by a happy experiment.

Mercury weighs $13\frac{1}{2}$ times as much as water. If, now, he argued, the atmospheric air can support a column of thirty-two feet of water, it must also be able to sustain a column of mercury of about one-fourteenth that height. The experiment is easily made. A glass tube of upwards of thirty inches in length, and closed at one end, is filled with mercury; and the finger being firmly pressed on the open upper end, the tube is inverted, and the end closed by the finger is plunged into a vessel containing mercury, CD. The finger being now withdrawn, the liquid in the tube descends, however long the tube may be, till it stands at the height of about thirty inches above the level of that in the vessel.

Fig. 25.

All doubt on the subject was shortly after put an end to by the celebrated Pascal, who caused the Torricellian tube, as it was called, to be carried up the Puy-de-Dôme, a mountain in France. By ascending a mountain, a part of the atmosphere is left below; if it is the pressure of the superincumbent atmosphere, then, that sustains the column, the mercury must sink further and further as the elevation is greater. Such was found to be the case, and the question was set at rest for ever.

That air is ponderable, or has weight, can be put to direct proof. By means of an instrument called an air-pump, to be afterwards described, vessels of a certain construction can be emptied of the air that in ordinary circumstances fills every space not occupied by other matter. When a hollow globe of glass or of copper, holding a cubic foot, is thus emptied of air, and weighed, on admitting the air again, it is found to be about an ounce and a quarter heavier than before. As a cubic foot of water weighs 1000 ounces, water is thus about 800 times heavier than air.

The tube of Torricelli gives us an exact measure of the weight and pressure of the whole atmosphere. If the tube (fig. 25) is an inch in area, the column of mercury, PE, thirty inches high, weighs about fifteen pounds. This weight rests on the mercury within the tube at P, the level of the general surface, and, by the law of liquid pressure already established, would press it down, and raise the level of the surface without, were not that surface equally pressed by the atmosphere. The atmosphere, then, rests with a weight of fifteen pounds on every square inch of surface. By multiplying the number of inches on the surface of the globe by fifteen, the product is the weight of the whole atmosphere in pounds. It is the same as the weight of an ocean of mercury spread over the whole globe to the uniform height of thirty inches, or of one of water thirty-four feet deep, or of one of oil thirty-seven feet deep.

THE BAROMETER.

In the Torricellian tube above described, we have the well-known instrument called a *barometer* (from two Greeks words signifying 'weight,' and 'measure'). The weight of the atmosphere is liable to fluctuations, and these are marked by the rising and sinking of the top of the column at E, which varies, at the level of the sea, from 28 to 31 inches, the average height being 29·7. A scale is attached to the tube to mark the rise and fall. It is important to observe that the height of the column is counted from the level of the mercury in the open vessel, and that this level is not steady. If the column sink, for instance, part of the mercury in the tube descends into the basin, and raises the level of the surface. When the basin is comparatively wide, the rise is insignificant, and is seldom attended to; but where great accuracy is required, either the scale is so constructed as to allow for the alteration of level, or the bottom of the basin is made flexible, and can be raised up and down by a screw, so as to bring the surface of the mercury always to the same point on the outside of the tube.

Barometers are of various constructions, according to the uses they are intended for. The common *weather-glass* consists of a glass tube, upwards of thirty inches in length, closed at one end A, and bent upwards at the open end C, as represented in fig. 26. The mercury requires to be introduced with great care into the tube, and boiled in it to expel all air; so that when it sinks down there may be a perfect vacuum at AE. The height of the column sustained is here to be counted from E down to a point on the tube on a level with F, the surface of the fluid in the open end. On the surface of F there floats a small ball, from which a thread is passed over a pulley G, and kept stretched by a lighter ball W. When the column at E sinks, the surface at F rises, and carries up the float, and the friction of the string turns the pulley, and with it the index H, whose motions are marked by a graduated circle. Such instruments are not capable of any great accuracy in ascertaining the actual height of the column; they indicate, however, generally whether it is high or low, and whether it is rising or falling, and these are the chief points in prognosticating the weather. (See METEOROLOGY).

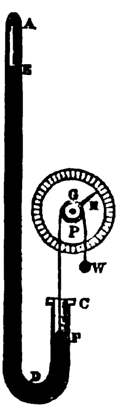


Fig. 26.

ELASTICITY OF GASES.

The laws which regulate the pressure of gases are essentially the same as those already established with regard to liquids. The fundamental fact of *transmitting pressure equally in all directions*, is as true of the one class of substances as of the other. But the effects in the case of gases are much modified by their peculiar property of *elasticity*, which requires careful consideration. The elasticity of gases involves two things—compressibility and expansibility, and in the case of common air, both properties are without any known limit.

1. Air is unlimitedly *compressible*, and that according to a remarkable law. Let *ab* be a barrel or cylinder twelve inches long, closed at *b*, and open at *a*, having an air-tight piston, *d*, moved up and down by the rod *c*. Before the piston is inserted, the air in the cylinder sustains the usual pressure of the atmosphere, which is resting upon it at the open end *a*; and if the area is an inch, the amount of the pressure is 15 pounds. When the piston is placed on the open end, and about to enter, the direct action of the outer air is cut off, but it continues to act on the upper side of the piston, so that the column inside still sustains 15 pounds. Let the rod be then loaded with weights till the piston descend through half the cylinder, so as to squeeze the confined air into half its original bulk; it will be found that 15 pounds have been laid on. The piston is now forced down with a weight of 15 pounds in addition to the weight of the outer atmosphere; the pressure on the confined air is thus exactly *doubled*, and the effect is to compress it into *half* the space. If the weight is *tripled* by adding 15 pounds more, the piston descends two inches further to *e*, and the air is reduced to *one-third* of its original bulk. An additional 15 pounds, making in all *four* atmospheres, will sink it to *f*, *one-fourth* from the bottom; and *twelve* atmospheres will leave the air confined between *b* and *g*, *one-twelfth* of the whole space. This regular progression, which is known as *Mariotte's Law*, from the name of its discoverer, holds good, without variation, for atmospheric air up to at least twenty-seven atmospheres.

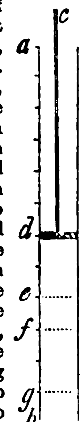


Fig. 27.

It follows from this that the elastic force or tension of compressed air—that is, the force with which it seeks to expand—is exactly equal to the compressing force, and inversely, as the space it occupies. At *f*, the air in the cylinder reacts upon the piston with a force of four atmospheres; at *d*, where it occupies twice the space, it presses up the piston with a force of only two atmospheres; at *a*, the under side of the piston is pressed with a force of one atmosphere, so as exactly to balance the weight of the external air.

2. Air is *expansible* without limit. The spring of air is not like that of a compressed feather or of a piece of India-rubber, which loses its tension as soon as it regains its original condition; air cannot be said to have any original volume, for it is always striving to occupy a larger space. Suppose an opening at the bottom of the cylinder (fig 27), and let the piston be at *f*; its upper and under sides sustain each 15 pounds, for the external atmosphere is admitted to both; and air, like water, presses equally in all directions, up as well as down. If the opening is now closed by a plug or a stop-cock, cutting off the external air from acting on the under side, the piston will not move, because the confined air presses on the under side, not by its weight, but by its expansive force, as much as the external air on the upper. Let the piston be next drawn upwards, and the air will not only follow it, but will continue to press upon the under side of it, though with a diminishing force. When the piston has risen to *d*, the air occupies twice its original bulk, and its tension or pressure against the under side of the piston is reduced to one-half, or $7\frac{1}{2}$ pounds; and if its volume is again doubled by drawing the piston to *a*, its elastic force falls to one-fourth, or $3\frac{3}{4}$ pounds. Thus the law of Mariotte holds for rarefied air as well as for condensed air. If the piston is drawn up with the hand, the gradually diminishing elastic force of the air within the

cylinder is sensibly felt. What the hand has to sustain, beyond the resistance of friction, is the difference between the two pressures on the opposite sides of the piston. That on the upper side continues a constant weight of 15 pounds; at starting from *f*, the two are equal, but the difference gradually increases until at *a* it is 11¼ pounds.

HEIGHT OF THE ATMOSPHERE.

If we assume air at the level of the sea to be, in round numbers, 800 times lighter than water, then, since water is 13½ times lighter than mercury, it follows that air is 13½ × 800, or nearly 11,000 times lighter than mercury. In order, therefore, to balance the column of mercury in the barometer, which is 2½ feet high, a column of air of the above density would require to be 11,000 times 2½ feet, or 27,500 feet high, which is nearly five miles. And this would actually be the height of our atmosphere if air were, like water, of uniform density throughout its whole depth.

It is evident, however, that the atmosphere is many times higher than five miles. Light clouds are seen floating above the highest mountains, such as Kinchinjunga, which exceeds 28,000 feet. And not only this, but we know, from the elastic property of air above explained, that the atmosphere cannot be uniform to the top, but must become rarer and rarer as we ascend. An ascent of about 500 feet from the level of the sea, makes the barometer fall half an inch, shewing that a sixtieth part of the weight of the atmosphere is left below. The air at this height, then, is relieved of $\frac{1}{60}$th of the pressure that confines it at the sea-level, and by the law of elasticity, becomes proportionally enlarged in volume; so that to get above another sixtieth part of the mass of the atmosphere, we must ascend more than 500 feet; and so on in increasing ratio. At the height of about three miles, one-half the mass of the air is below; the density at that point is reduced to one-half, and an ascent of 500 feet would produce only half the fall of the barometer that is produced at the earth's surface. The upper half of the atmosphere must thus occupy a depth many times that of the lower half. The regular progression in the increasing rarity of the successive strata of the atmosphere, which would arise from Mariotte's law, is true only on the supposition that the temperature is the same throughout. But the capacity of air for heat increases with its rarity, so that the temperature of the atmosphere diminishes as we ascend. This loss of heat diminishes the elastic force of the air in the upper regions, and makes it expand less under the diminished pressure than it would otherwise do. Cold, then, may be said to check the indefinite upward extension of the atmosphere. As this cold goes on increasing, and also the distance between the atoms of the air, the repulsive force which tends to separate the atoms further and further, must at last become so weak, that the gravity of the upper layer of atoms is able to resist it, and to keep them from rising higher. It would thus appear from theory, that there is a definite boundary to the atmosphere; and from observations made as to the effects on rays of light in passing through the upper regions of the air, it is concluded that the limit of its height is forty or fifty miles.

Measurement of Heights by the Barometer.—Though the same difference of elevation does not at all stages in the ascent give the same rise or fall of the barometer, yet, by means of the known law of expansion, it is possible, from knowing the heights of the barometer at two stations, and a number of other circumstances, to calculate the elevation of the one above the other. Besides the height of the barometer at the two stations, it is necessary to observe the temperature, for this affects not only the length of the column of mercury in the barometer, but also the density of the atmosphere, both of which must be allowed for. The latitude of the place has also to be taken into account; for the force of gravity varies from the equator to the poles (see NATURAL PHILOSOPHY), and this affects the density of the air. Altogether, the rule is too complex for explanation here.

THE AIR-PUMP.

The air-pump, by which air is removed from vessels, acts by means of the expansibility of the fluid. One form of an air-pump is represented in fig. 28. R is the glass-receiver, or vessel to be exhausted, standing on a smooth plate SS, and fitting so exactly, that no air can penetrate between them. From the middle of the plate, there runs a channel or tube, AB, into the barrel of the pump. The piston, P, is represented as above the opening of the channel, with its rod, C, passing through an air-tight collar D. When the piston is forced down past the opening, it cuts off the air in the barrel from that in the receiver, and compresses it so as to make it open the valve, V, and escape. When P has reached the bottom, and begins to ascend again, the valve closes, and prevents air from entering. In the meantime, the air in the receiver has by its expansion refilled the barrel, and is now rarer; the piston again descends, and expels another portion, and so on. It is obvious that in this way the whole air can never be expelled; as the contents of both receiver and barrel are equally rarefied, each stroke expels less and less. The best air-pump always leaves a residuum.

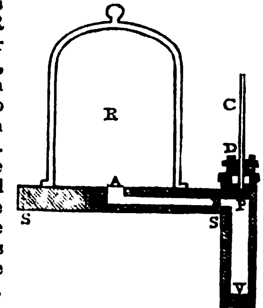


Fig. 28.

The *condensing pump*, or syringe, represented at *ik*, fig. 29, is the counterpart of the exhausting air-pump. By means of it, a receiver can be charged with an amount of air that would fill it many times at the ordinary density, and experiments can thus be tried on bodies enclosed in the receiver, under the pressure of many atmospheres.

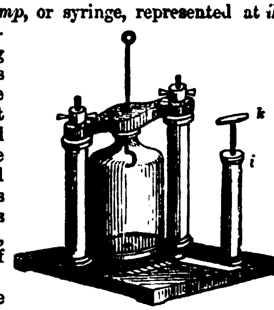


Fig. 29.

A condensing syringe is used for charging the chamber of air-guns. The valve of this chamber being then suddenly opened by the trigger, a portion of the highly compressed air is allowed to escape into the barrel behind the ball, which it propels with great velocity.

By means of the exhausting air-pump, many interesting experiments are performed, illustrative of the pressure of the atmosphere. If a bladder, half full of air, and tightly tied at the neck, be placed under the receiver, as the exhaustion proceeds, the bladder will expand by the removal of the external pressure, and seem as if ready to burst. Dried raisins, or shrivelled apples, will in like manner swell out, and have all the plumpness of new fruit; and an egg, by the expansion of its confined air, will explode. A mouse placed below the receiver, and deprived of air, immediately dies from want of breath.

It is the atmosphere that retards the falling of bodies of a light and porous nature; and therefore, in the exhausted receiver of an air-pump, all such bodies descend with the same velocity as those of a heavy compact nature. A piece of coin and a feather let fall at the same instant of time from a hook within the top of an exhausted receiver, will strike the bottom at the same moment.

Boiling-point under different Pressures.—If water is boiled in a glass flask, and then allowed to cool

several degrees below the boiling-point; on being placed under the exhausted receiver, it will again begin to boil briskly, and will continue to do so for some time. This shews the connection between the pressure of the air and vaporisation. Under the usual pressure, water boils at 212°, alcohol at 172°, ether at 98°, oil at 600°. But as the pressure is removed, the boiling-point in each case becomes lower. On the top of Mont Blanc, water is found to boil at 187°; and in a complete vacuum, liquids in general are stated to boil at a temperature 140° lower than in the open air. Increased pressure, again, raises the temperature of the boiling-point. This is taken advantage of in extracting gelatinous and oily matter from bones, &c. The bones are boiled in a strong vessel where the steam may be confined, and made to press on the liquid. A pressure of two atmospheres raises the temperature to 250°. In distilling liquors, and in making vegetable extracts, on the other hand, it is often desirable to avoid such a high heat as 212°, which is apt to injure the substances, and in such cases the processes are carried on under a partial vacuum. In boiling down the juice of the sugar-cane to the crystallising point, this expedient is employed with great advantage.

It thus appears that boiling water is not equally hot at all places on the earth. At Quito, for instance, which is at an elevation of 9000 feet, water boils at 194°; and this temperature is too low for cooking many substances. Even at the same place, boiling water is hotter on a day when the barometer stands above thirty inches, than when it stands at twenty-eight inches.

Heights measured by Boiling-point of Water.—Vapour of water or steam has a certain tension, or elastic force, according to its temperature (see STEAM-ENGINE). Thus, at 32°, its force is able to sustain 0·2 inch of mercury; at 80°, it supports 1 inch; at 150°, 7·42 inches; at 180°, 15·5 inches; at 212°, 30 inches, or the whole pressure of the air. Now, whatever is the temperature of vapour that can support a given pressure, the same is the temperature at which water boils under that pressure. By observing, therefore, the temperature at which water boils, we can find, from a table of the elastic force of vapour at different temperatures, the pressure in inches of mercury, to which it is subject at the time, and thus make the thermometer a substitute for the barometer. Accordingly, heights are often determined by the boiling temperature of water. Beginning at the level of the sea, a fall of 1° in the boiling-point corresponds to a difference of elevation of 510 feet, or 51 feet for one-tenth of a degree. At an elevation of 2500 feet, the difference for a degree is 520 feet; at 5000 of elevation it is 530; and at 17,000, it is 590. An approximation may be made for medium elevations, by multiplying 530 feet by the number of degrees of difference in the boiling-point between the two stations. Thus, if the boiling-point at the foot of a mountain were 210°, and at the top 202°, the height above the station at the bottom would be about 530 × 8, or 4240 feet. In order to allow for the temperature of the air, &c., certain tables are necessary, such as those given by Colonel Sykes in 'Hints to Travellers' (*Royal Geographical Society's Journal*, vol. 24). 'The results,' says Colonel Sykes, 'of six years' experience justify me in saying that common thermometers may be satisfactorily used to supply the place of barometers in measuring heights where great accuracy is not required; and it will be recollected that what is usually looked upon as a difficult and troublesome operation with barometers, will be attainable by any person who carries with him a couple of thermometers, the requisite tin pot, and the tables, and who is master of the simplest rules of arithmetic.'

The experiment of boiling water under diminished pressure may easily be performed without an air-pump. Take a common olive-oil flask, and fit it with a good sound cork. Fill it one-third with water; and when it has been brought to boil briskly over a spirit-lamp, or a gas flame, insert the cork, withdrawing it from the flame at the same instant, and then place it in a support, bottom upwards. The ebullition will cease after a short time; but by pouring cold water over the upper part of the flask, it can be renewed again and again. The explanation is, that the space above the water in the flask is filled with nothing but steam, and when this is suddenly condensed by cooling the glass, the surface of the water is relieved from pressure, and the boiling is renewed, until the steam generated again cause as much pressure as to check it.

Gases dissolved in Liquids.—Liquids contain a certain amount of air and other gases dissolved in them. The molecules of the dissolved gas adhere apparently to those of the liquid with a certain force, sufficient to condense the gas into much less than its natural bulk; and a liquid can hold more of a gas thus imprisoned the greater the pressure it is under. This is most strikingly seen in the case of effervescing liquids, such as beer. Carbonic acid gas is generated in the beer by fermentation; under the usual pressure of the atmosphere, the liquid can hold a certain amount of this dissolved, and the rest escapes. But when a bottle of it is closely corked, the pressure on the surface continues to increase till it is equal perhaps to two atmospheres, and enables the liquid to hold an additional amount of gas in solution. If the cork is now removed, this additional portion separates from the liquid to which it was adhering in a dense, perhaps liquid form, and starts into its own aëriform shape, appearing as minute globules all through the mass, and rising towards the surface. After standing in an open glass for some time, the beer becomes apparently flat and dead, as if all the gas had escaped. But that this is not the case, may be shewn by placing it under the receiver of the air-pump; on the first stroke, specks of gas make their appearance in all parts of it, and it soon froths up, as if newly drawn.

When a glass of common spring or river water is in like manner placed under the receiver, it is seen to contain a considerable amount of common air dissolved in it. As the exhaustion proceeds, minute globules of air make their appearance all through the water, and rise in a stream to the top. A dense crop of bubbles is observed to form on the sides of the glass; this arises from a film of air having been condensed on the glass by adhesion (see NATURAL PHILOSOPHY) before the water was poured in, and from part of it now escaping under the diminished pressure.

PUMPS.

The effect of atmospheric pressure on water affords a convenient method of raising it above its ordinary level; this is effected by pumps, which may be termed both hydraulic and pneumatic machines. Fig. 30 represents the outline of a common suction-pump. It consists of a cylinder, furnished with a piston A, made to fit air-tight. In this piston there is a valve opening upwards, but here indicated as closed. When the piston is raised, the air under it is rarefied more and more at each stroke, and the pressure of the air upon the surface of the water on the outside of the tube forces the fluid into it. The valve B is at the same time opened upwards, and the water, after several strokes, rushes in above it. When the upward stroke of the piston is complete, it is again depressed—the water passes through the valve in

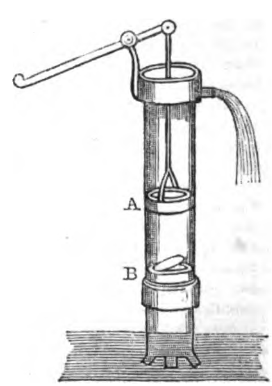


Fig. 30.

the piston, and on the next stroke it is discharged at the spout.

In this form of pump, the greatest height to which the water can be raised, counting from the level of the well to the bottom valve, is, in theory, thirty-four feet, when the level of the mercury in the barometer is thirty inches. In practice, however, owing to the imperfect vacuum, the height never reaches the above, the limit being more usually twenty feet. The space between the piston and the bottom valve should be as small as possible, to allow little space for the collection of vapour or air, this being more especially desiderated in force-pumps which are used to pump hot water.

The height to which water can be raised above its level, can be greatly increased by the use of the force-pump. In fig. 31, which is a diagram illustrative of the

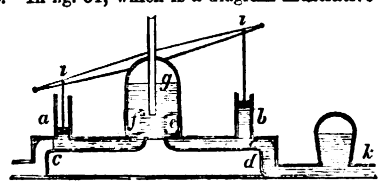


Fig. 31.

mechanism of a fire-engine, in which force-pumps are used to raise the water to the height required, the pumps are two in number, *a* and *b*, both being worked by the lever *ll*. The pistons are solid, and work water-tight in the pumps; valves *c*, *d*, are connected with the pipes which lead to the water to be pumped up; other valves, *f* and *e*, are placed at the ends of the pipes which lead to the air-chamber *g*. All these valves open upwards. On the piston *b* rising, the water flows through the valve *d*, forced by the atmospheric pressure, and fills the space below the piston. The depression of the lever *ll* at the end near *a* forces the piston of *a* down the pump, closes the valve *c*, and forces the water through the valve *f* into the air-chamber *g*. The water is prevented leaving this through the other pipe leading from *b* by the closing of the valve *e*. The air which is compressed in the upper part of the chamber *g* presses upon the surface of the water contained in it, and causes the water to rush out from the orifice of the pipe in a nearly continuous stream.

It is clear that, both in the suction-pump and in the force-pump, the motion of the water is intermittent; which circumstance causes a great waste of power. It is calculated that in the majority of lifting and forcing-pumps, from 55 to 80 per cent. of the power is expended in giving a velocity to the water in the first instance, which velocity has to be suddenly checked, so that it is not available as working-power. The evil of the intermittent nature of the action is aggravated by a variety of causes:—First, the small size and faulty construction of the valves. By increasing the size of these, the sudden change in the section and velocity of the stream would be avoided. As the variation of the velocity is dependent upon the ratios of the suction-pipe and force-pipe to the barrel, attention should be paid to attain to an approximation of these. This want of due proportion is a second cause of loss of power. The third cause stated is the neglect to make the extremity of the suction-pipe where the water enters it such as to render the contraction of the vein as small as possible. In HYDRAULICS, we have seen that the discharge of water from a pipe depends upon the shape of the orifice. It has been found that an equal effect is obtained by attending to the shape of the orifice at which it enters. By expanding, then, the lower extremity of the suction-pipe where it enters the water into the shape of a cone, the diameter of the wider end being 1·2 times that of the narrower, the contraction of the vein may be nearly destroyed. By similarly expanding the discharging orifice, a discharge will be obtained greater than that due to the section of the pump. A fourth cause of loss is the neglect of the shape of the pipes where they unite with the *barrel*. The fifth is a very prolific cause of loss, and one which is by no means generally known or attended to: it is working force-pumps with too great a velocity. Space prevents us from going into an explanation of this cause of loss of power. The results of the investigation, however, prove that 'the proportions of a pump, to be worked by a given motive power, should be such, that the power to be expended at every stroke may just bring the water raised to rest at the end of each stroke.' The Jury Report of the Great Exhibition on pumps, from which we have compiled the above, has the following: 'A remedy for some of these evils in the working of a pump, has been sought in the application to it of a second air-vessel communicating with the suction-pipe immediately below the barrel, or with the top of the suction-pipe and the bottom of the barrel. The commencement of each stroke is eased by a supply of water from this air-chamber to the space beneath it. The influx of the water into that space is aided by the pressure of the condensed air in the air-chamber; and when the stroke is completed, the state of condensation of this air is, by the momentum of the water in the suction-pipe, restored, causing it to rush through the passage by which that pipe communicates with the air-chamber.' In fig. 31, *k* shews the position of the second air-chamber in the suction-pipe.

Centrifugal Pumps.—The evil of an intermittent current, to which common pumps are liable, is escaped in centrifugal pumps, which may be noticed here, though not pneumatic machines. A centrifugal pump is a hollow wheel traversed by vanes or arms curved or straight, and which is made to revolve rapidly; the water entering at the axis is put in rapid rotation, and is expelled at the circumference by its centrifugal force. The water is led to the wheel by a pipe which answers to the suction-pipe of a common pump; the wheel, however, is frequently made to revolve in the water which it has to raise—as in drains, lakes, &c. If the water is expelled from the wheel into a closed receptacle like that of the fire-engine, it forces a continuous stream up a pipe. There are two classes of centrifugal pumps—those in which the arms are curved, and those in which they are straight. Experience in the working of both kinds has amply proved that by using curved arms the greatest effect is obtained. In fig. 32

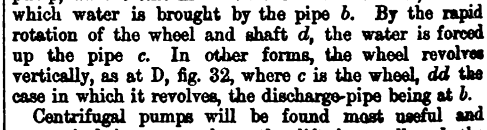


Fig. 32.

A shews a pump with flat, and B one with curved, arms or vanes. The wheel in some forms revolves horizontally, as at C, in fig. 32, which is a sketch of Bessemer's pump, *aa* the case in which the wheel revolves, and to which water is brought by the pipe *b*. By the rapid rotation of the wheel and shaft *d*, the water is forced up the pipe *c*. In other forms, the wheel revolves vertically, as at D, fig. 32, where *c* is the wheel, *dd* the case in which it revolves, the discharge-pipe being at *b*.

Centrifugal pumps will be found most useful and economical in cases where the lift is small and the quantity of water to be raised considerable. As tidal pumps, they are particularly useful, for the lower the lift the greater the quantity discharged at the same speed. Since the level of tidal water is constantly changing, a greater amount of work will be obtained than by the use of ordinary pumps, for these can only raise their cubical contents, no matter what the lift. Centrifugal pumps are not only easily fitted up, but they are not apt to get out of repair, from the absence of valves and

complicated mechanism. This feature is also advantageous in another way, stones and other obstructions being easily passed through without damage.

Syphon.—The action of the syphon will be readily understood from the principles already illustrated. It is simply a bent tube, with one end inserted in a liquid, as represented in fig. 33. To begin the action, the air is withdrawn from the tube by means of the mouth or a syringe, when the liquid enters and fills it, as in other cases of suction. When the suction is stopped, there are two forces acting on the liquid in the tube—the pressure of the atmosphere on the liquid in the vessel, forcing it in the direction from C towards B and A, and the pressure at A, forcing it in the opposite direction. These two pressures are of themselves equal, and when the lengths of the columns of liquid in the two legs are equal, there is no flow; but when one column, as AB, is longer than the other, its weight destroys the balance, and produces a flow towards itself. The length of the column BC, is counted from the level of the liquid, not from the mouth of the tube. It is clear that the height of B above C can never exceed thirty-four feet.

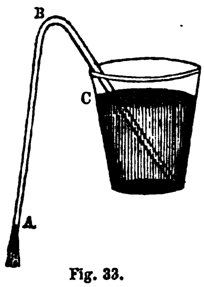


Fig. 33.

OTHER EFFECTS OF ATMOSPHERIC PRESSURE.

Pressure on the Human Body.—The body of a man has, on an average, a surface of about 2000 square inches. At the rate, then, of fifteen pounds to the square inch, the whole pressure which a person of an ordinary size sustains on the surface of his body is 30,000 pounds, or nearly fourteen tons. It gives a wrong notion of this pressure to speak of it as a load. It has, on the contrary, a buoyant effect, and makes a man lighter, or press less on the earth, than he would without it (see below). Air presses on all sides of a body immersed in it. It is therefore a compressing or crushing force, and does not at all act as a weight. The reason why this compression is not felt, and does not in effect squeeze the body into less bulk, is that there is an equal pressure *outwards* at all parts. In fig. 1, a force of a pound pressing in the plug *a*, is felt as an equal force pressing out the plug *b*. Now, the blood and other liquids in the body, though contained in tubes, transmit pressure through all their ramifications, as the water in the box B does through its mass; and the direct pressure of the atmosphere on any spot of the outer surface, tending to squeeze in the sides of the tubes containing the fluids, is met by an equal pressure on the part of the fluids, to force out the sides of the vessels, which outward pressure itself is caused by the atmosphere pressing on other parts of the system.

We are as little sensible, in ordinary circumstances, of this outward pressure of the fluids on the vessels of the body, as we are of the compressing force of the atmosphere. But it makes itself felt whenever the external pressure is removed from any part, as in the familiar act of sucking the finger, or more strikingly in the operation of cupping. A small bell-shaped glass, in which the air has been rarefied by burning a slip of paper, or by other means, is suddenly applied to a flat surface of the body. The small portion of air under the glass, as it cools, presses with diminished force on the surface of the skin; and the fluids within, released from the usual check, swell out the vessels and skin, and if a wound has been made with a lancet, the blood is forced out. When the usual pressure of the atmosphere is much diminished over the whole body by ascending great heights, uneasy sensations are often felt, occasioned most likely by air contained in the liquids and in cavities of the solid parts of the body, seeking to expand.

Boy's Sucker.—A boy's sucker affords a good illustration of the operation of atmospheric pressure. A piece of moist leather is pressed against a smooth stone, so as to exclude all air from between them. They are now held together with a force of fifteen pounds on the square inch. By beginning at the edge, they could be separated easily, because the air fills up the interstice as it is formed. But if a string is attached to the middle of the leather, as represented in fig. 34, and pulled upwards, separation is resisted. If, by a strong pull, a portion—say a square inch—of the leather is raised up, there is a vacuum under it, and the weight of the atmosphere on the upper side of that inch has to be borne up by the hand. With regard to the stone, again, we have to consider that before the vacuum was formed, the atmospheric pressure on its under side was exactly equal to that on its upper side; the two counteracted one another, and produced no effect, either in increasing or lessening the weight of the stone. But the effect of the vacuum is to remove the pressure from an inch of the upper surface, so that on the square inch of the under surface opposite the vacuum there is an upward pressure of fifteen pounds which is not counteracted; and by this amount of force the stone is pushed up. If not too heavy, it may thus be lifted by means of the sucker. Correctly speaking, the sucker does not lift the stone; it only lifts the weight of a column of the atmosphere from off the stone, and thus allows the remaining atmospheric pressure to push it up.

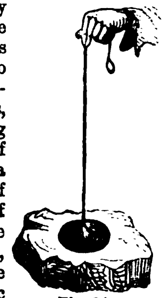


Fig. 34.

The feet of flies, and some other insects, are formed on the principle of the sucker; and by this means they can walk on the ceiling of a room, or on an upright smooth pane of glass. When deprived of the extremities of its legs, on which the apparatus for adhesion is situated, a fly can no longer climb an upright surface, or walk on a roof with its back downwards, though it can walk on the surface of a table without apparent difficulty. Limpets and other testaceous animals adhere to rocks by causing a partial vacuum within their shells, which they accomplish by contracting themselves into less bulk.

Bird-cage Fountain—Vent-peg, &c.—It is surprising at first sight, that in ink-bottles of the kind represented in fig. 35, and in bird-cage fountains, which are of much the same make, the liquid should stand as high as the top at A without flowing out at C. But the very same cause sustains it that sustains the column of mercury in fig. 26, and keeps it from flowing out at C—the atmospheric pressure, namely, on the surface at C, while the top at A is close, like the top of the tube in fig. 26. The greater width of the bottle makes no difference, the pressure of liquids being not as width, but as depth (see page 226.) The atmospheric pressure on C would be able to keep up the liquid in the bottle till it reached the height of thirty-three feet, or thereby. The ink is introduced into a bottle of this kind by inclining it over, and pouring in gradually at C. When the ink in the tube CB sinks down by use to the level of the horizontal communication, a bubble of air gets in, and rising to the top at A, fills part of the space, and forces down a portion of ink into C.

Fig. 35.

On the principle now explained, if the lid of a tea-pot were quite close, so as to exclude the pressure of the atmosphere from the top of the liquid within, the liquid

could not be poured out. It is for this reason that in drawing liquor from an opening in the lower part of a cask, there must be a vent-peg at the top to admit air.

Every one knows that when a full bottle is turned mouth downward, the liquid cannot flow out but in proportion as air can pass in. It is instructive to mark the difference between the case of a common bottle inverted, and the case of the ink-bottle, fig. 35. The atmosphere pressing upon the downward surface of the liquid in the neck of the bottle, prevents it from *descending* as strongly, as it prevents the ink from *ascending* in the tube at C. But air being lighter than the liquid, bubbles of it enter the downward surface, and ascend to the top, where their elastic pressure overcomes that of the outward air, and forces down the liquid; while, before a particle of air could get to the top of the ink-bottle, it would have to *descend* through the liquid in the tube C, which the comparative specific gravity of the two fluids prevents.

A liquid will not flow at all even from a downward opening in a vessel close at the top, provided the air be prevented from entering the surface in bubbles, and rising up through it. If we conceive a thin disk of caoutchouc inserted in the lower end of the tube, fig. 25, so as to slide up and down without resistance, and yet be air-tight, the tube might be lifted from the cistern without the mercury falling out. A simpler way of illustrating the same principle is the following :—Take a common wine or ale glass, with as even edges as possible, fill it brimful with water, and on the top lay a round disk of smooth stiff writing-paper, rather larger than the mouth of the glass. Above this, place a book, and pressing it down, invert the whole, so that the glass shall stand on the book with the mouth downwards, and perfectly horizontal. In this position, the glass may be lifted up from the book with the paper adhering to its mouth, and the water hanging in it apparently without support.

BUOYANCY IN AËRIFORM FLUIDS.

The fundamental law in this is exactly the same as in liquids (see page 229). A body in air displaces its own bulk of the air, and is borne up with a force equal to the weight of the air so displaced. If the body's own weight is less than this, it must rise up, as a piece of cork does in water; if greater, the body only loses a portion of its weight, as a stone in water.

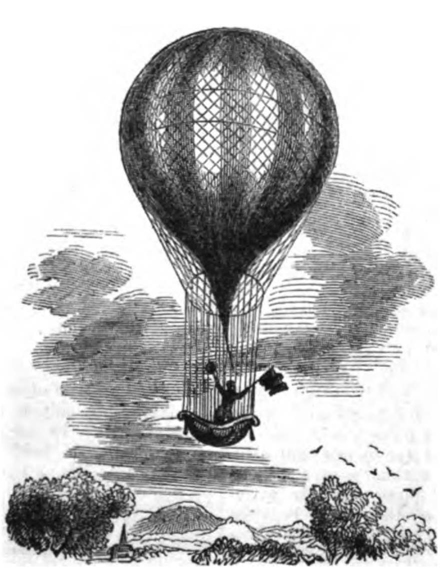
In weighing bodies in air, the fact that the air deprives them of part of their weight, does not interfere with the accuracy of the process so long as the substance is nearly of the same density as the weight against which it is balanced, because then both are equally affected. But where there is great difference of density, it leads to sensible error. A pound of feathers—as it is sometimes paradoxically stated—is heavier than a pound of lead; that is, it contains more matter. If a quantity of feathers occupying a cubic foot of space, were balanced in a vacuum against a piece of metal, the balance would be destroyed on taking them into the air. The feathers would lose above an ounce—the weight of a cubic foot of air—the metal would lose only a few grains.

BALLOONS.

Solid bodies cannot of themselves float in air, being all heavier than an equal bulk of it; but by enclosing air rarefied by heat, or a light gas, such as hydrogen, in a bag, it may be made to buoy up more or less solid matter along with it. Such a contrivance is a balloon. A soap-bubble blown from hot water with warm air, is the simplest form of balloon, but soon loses its buoyancy by cooling; if blown with hydrogen, it continues ascending till it bursts. A body floating in air rises till it arrives at a stratum of the atmosphere whose density is the same as its own.

A balloon is a bag made of varnished silk, and surrounded by a net-work, from which a car is suspended. Balloons were originally filled with heated air, and had a fire suspended in the opening below to keep up the temperature. So far as lightness is concerned, hydrogen would be the best gas for the purpose; but, from its cheapness, common coal-gas is generally employed, whose density is rather more than half that of air.

The air contained in a room fifty feet long, thirty wide, and twenty high, weighs upwards of a ton. A balloon of this capacity (30,000 cubic feet) would thus displace a ton of air, while the gas contained in it weighed only half a ton; it would therefore ascend with a force equal to the difference, or half a ton after deducting, of course, the weight of the silk, and other parts of the apparatus. The greatest elevation ever reached in a balloon was by Gay Lussac; the barometer sunk to 12 inches, and the height was computed at 23,000 feet, or 4⅓ miles. The ascent and descent of a balloon can be regulated by means of valves for allowing gas to escape, and of ballast which can be thrown out at pleasure; but the impossibility of guiding the horizontal motion, renders the art of *aërostation*, as it is called, only a matter of amusement.



OPTICS—ACOUSTICS.

OPTICS.

THE term *Optics* is derived from a Greek word which signifies *seeing*, and applies to that branch of natural philosophy which treats of the phenomena of *light* and *vision*. Of the precise character of light there are various theories, but none which admits of actual demonstration or proof. By some it has been described as consisting of very minute particles or molecules, which are thrown off from what are called luminous bodies in all directions, and with immense velocity; while others consider it as the effect of an undulation or vibration produced by luminous bodies in the thin and elastic medium which is interposed between them and the seat of our vision—this vibration producing an effect upon our organs, which we recognise as light, in a manner analogous to the impression of sound on the ear caused by vibrations of the atmosphere. The latter is called the *undulatory* theory of light; and the former—in which light is supposed to consist of *material* particles—the theory of *emission*.* Whatever may be the cause or absolute nature of light, we know it is a property of luminous bodies which enables us to see the luminous objects themselves, as well as others in their vicinity, and that its absence produces darkness.

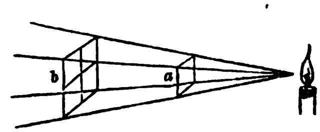
All visible bodies may be divided into two classes—*self-luminous* and *non-luminous*. Under the first head are comprised all those bodies which possess in themselves the property of exciting the sensation of light or vision, such as the heavenly luminaries, terrestrial flames of all kinds, phosphorescent bodies, and those bodies which shine by friction or by being heated. Under the second class we recognise such bodies as have not of themselves the power of throwing off particles or undulations of light, but which possess the property of reflecting the light which is cast upon them from self-luminous bodies. A non-luminous body may thus, by reflection, receive light from another non-luminous body, communicate it to a third, and so on. All reflected light, however, is inferior in brilliancy to that which comes direct from a self-luminous body.

Anciently, it was believed that light was propagated from the sun and other luminous bodies instantaneously; but the observations of modern inquirers have shewn that this was an erroneous hypothesis, and that light, like sound, requires a certain time to pass from one part of space to another, though the velocity of its motion is truly astonishing, as has been manifested in various ways. Astronomers have proved, by observing the eclipses of Jupiter's satellites when that planet is nearest and when it is furthest from the earth, that light moves from the sun to the earth—a distance of 95,000,000 miles—in seven and a half minutes, or about 200,000 miles during a single vibration of a pendulum. So prodigiously great is this velocity, that, as far as any common observation is concerned, light may be regarded as perfectly instantaneous in its action.

* The theory of emission was devised by Newton, and for a long time it was thought to explain the facts better than any other. It is not necessary to suppose that the particles succeed each other closely, so as to crowd the whole of space with a luminous stream. It is found that a single impression of light will remain on the eye for the eighth of a second, and therefore if eight particles fell upon it every second, there would be a permanent impression produced. But in the eighth of a second a ray passes through 25,000 miles, so that if one particle followed another at this distance, constant light would be maintained, and the shower would be so thin and scattered, as to allow room enough for all the innumerable crossings of luminous rays. At present, however, there are many phenomena which cannot be explained by this theory, and are found more consistent with the undulatory hypothesis.

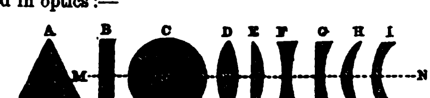
Light proceeds in a straight direction from the luminous body which produces it, towards the part or situation against which it is permitted to act. In consequence of this directness, a shadow or darkened spot is observable behind any opaque object presented to the light. During night, we are in the earth's shadow; and this shadow reaches so far beyond us into space, that when the moon plunges into it in her course, she undergoes an eclipse.

In proportion as light advances from its seat of production, it diminishes in intensity. The ratio of diminution is agreeable to that which governs physical forces—that is, the intensity of the light will diminish as the square of the distance increases, or at the rate of 1, 4, 16, &c. But in proportion as we lose in intensity, we gain in volume; the light is the weaker the further it is from the candle, but it is filling a wider space. Thus, if a board *a*, a foot square, be placed at the distance of one foot from a candle, it will be found to hide the light from



another board *b*, of two feet square, at the distance of two feet from the candle. Now, a board of two feet square is just four times as large as one of one foot square, and therefore the light at double the distance being spread over four times the surface, has only one-fourth the intensity.

Preliminary to any further exposition of the nature and action of light, we offer the following definitions of terms:—Any parcel of rays passing from a point is called a *pencil* of rays. By an optical *medium* is meant any pellucid or transparent body—as, for example, air, water, or glass—which suffers light to pass through it. *Parallel rays* are such as move always at the same distance from each other. If rays continually recede from each other, they are said to *diverge;* if they continually approach each other, they are said to *converge.* The point at which converging rays meet, is called the *focus;* the point towards which they tend, but which they are prevented from coming to by some obstacle, is called the *imaginary focus.* When rays, after passing through one medium, on entering another medium of different density, are bent out of their former course, and made to change their direction, they are said to be *refracted;* when they strike against a surface, and are sent back again from the surface, they are said to be *reflected.* A *lens* is a glass ground into such a form as to collect or disperse the rays of light which pass through it. These are of different shapes, and thence receive different names. The following figures individually represent sections of the variously shaped lenses and other glasses used in optics:—



A is a triangular stalk of pure glass, of which we have here a cross sectional or end view, and which is called a *prism;* each side of the prism is smooth. B is a section of a piece of plane glass, with sides parallel to each other. C is a sphere or ball of glass, and consequently

is convex on all parts of its surface. D is a piece of glass convex, or bulging on its two sides, and is called a *double convex lens.* It is this kind of lens which is used for magnifying objects, in spectacles, telescopes, and other instruments. E is a *plano-convex lens,* flat or planed on one side, and convex on the other. F is a *double concave lens,* or glass hollowed on each side. G is a *plano-concave lens,* or planed on one side, and concave on the other. H is a *meniscus,* or lens convex on one side and concave on the other, both surfaces meeting, and of which we have an example in watch-glasses. I is an example of the *concavo-convex lens,* in which the surfaces disagree, or do not meet when continued. In all these lenses, an imaginary line, represented by MN, and passing through the centres of the surfaces, is called the *axis.*

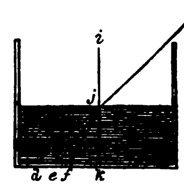
In treatises on optics, it is customary to divide the subject into two sections, under the heads Dioptrics and Catoptrics. The term *dioptrics* is compounded of two Greek words signifying to *see through,* and refers to the transmission of rays of light through transparent bodies, and the laws which such rays observe. *Catoptrics* is also from the Greek, and signifies to *see from* or *against:* it refers to the reflection of light from surfaces, and the formation of images by means of mirrors and other objects.

REFRACTION OF LIGHT.

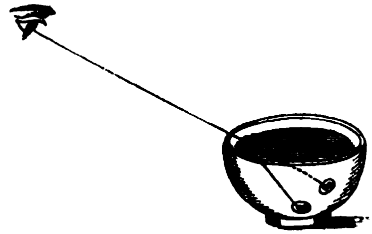
Refraction, as already mentioned, is the bending of rays of light from the course they formerly pursued. If the rays, after passing through a medium, enter another of a different density, perpendicular to its surface, they are not refracted, but proceed through this medium in their original direction. For instance, if the sun's rays were to strike upon the surface of a river at right angles, or perpendicularly, to its surface, they would go straight to the bottom, and the line they observed in the air would be continued in the water. But if they enter obliquely to the surface of a medium either denser or rarer than what they moved in before, they are made to change their direction in passing through that medium; that is, they are refracted.

The mode of the refraction depends on the comparative density or rarity of the respective media. If the medium which the rays enter be denser, they move through it in a direction nearer to the perpendicular drawn to its surface. On the contrary, when light passes out of a denser into a rarer medium, it moves in a direction further from the perpendicular. This refraction is greater or less—that is, the rays are more or less bent, or turned aside from their course—as the second medium through which they pass is more or less dense than the first. To prove this in a satisfactory way, take an upright empty vessel into a darkened room, which admits but a single beam of light obliquely through a hole in a window-shutter. Let the empty vessel stand on the floor, a few feet in advance of the window which admits the light, and let it be so arranged that, as the beam of light descends towards the floor, it just passes over the top of the side of the vessel next the window, and strikes the bottom on the side furthest from the window. Let the spot where it falls be marked. Now, on filling the vessel with water, the ray, instead of striking the original spot, will fall considerably nearer the side towards the window. And if we add a quantity of salt to the vessel of water, so as to form a dense solution, the point where the ray strikes the bottom will move nearer to the window. In like manner, if we draw off the salt water, and supply its place with alcohol, the beam of light will be still more highly refracted; and oil will refract yet more than alcohol.

Let the annexed oblong figure represent a vessel half filled with water, and R the ray of light which may be expected to pass through it to the bottom at *d.* The direction of the ray is perfectly straight until it enters the water at *j,* when, instead of proceeding in a straight line to *d,* it is bent from its course, and compelled to strike the bottom of the vessel at *e.* If oil instead of water had been used, the ray would have been still more bent, and have reached the bottom at *f.* If the ray had been sent directly downwards, as from *i* to the surface of the water at *j,* it would not have been refracted, but have proceeded straight to the bottom at *k.*



The following simple experiments are well known:—Take an empty basin and place it on a table, then lay a shilling at the bottom of the basin, in such a



position that the eye of the observer will not see it. Now fill the basin with water, and the shilling, though lying unmoved, will come completely into sight. The explanation of this phenomenon is, that the ray of light producing vision in the eye is bent on emerging from the water, and has all the effect of conveying our sight round a corner. In like manner, the refractive power of water is observable when we thrust a straight stick or instrument into it, on aiming at any object. We see that the stick seems to be bent, and fails in reaching the point which we desired it should. On this account, the aim by a person not directly over a fish must be made at a point apparently below it, otherwise the weapon will miss by flying too high. Persons who spear salmon in rivers require to calculate upon this refractive power in taking their aim.

With regard to the refractive power of transparent substances or media, the general rule, with certain limitations, is, that it is in proportion to the densities of the bodies. It increases, for instance, from the most perfect vacuum which can be formed, through air, fresh water, salt water, glass, and so on. Tables of the refractive powers of substances most interesting in optics will be found in Brewster's *Optics.* From these it would appear that substances which contain fluoric acid have the least refractive power, as inflammable ones have the greatest. As to the cause of refraction, or the way in which the bending of the rays is brought about, explanations are given both on the undulatory theory and on that of emission, but they are of too abstruse a nature to be introduced here.

The refraction of rays of light is observable in the case of common window-glass. The two sides of a pane not being perfectly parallel to each other, bodies seen through it appear as if distorted; and as the obliquities in the glass are very various, the distortions are equally grotesque and numerous. Some windows are purposely ground on the surface, to produce universal and minute refraction; and thus so great a confusion is introduced among the rays, that objects are not distinguishable through the glass. When the obliquities on the surface of one side of a piece of glass stand distinct from each other, so as to admit of refraction in a clear and distinguishable manner, then each obliquity affords a separate view of an object on the opposite side, and thus an object seems to be multiplied as many times as there are obliquities.

The refraction of light is observable on a great scale in relation to our atmosphere. The rays of the sun, on reaching the confines of the atmospheric fluid which envelops the earth, enter a medium of greater density than that which they have previously been pursuing, and consequently are refracted or bent. One obvious effect of this is, that we never see the sun in the actual position which he occupies. He is always less or more, in relation to our eyes, what the shilling is said to be in the above experiment with the basin of water. This is peculiarly the case in the morning, when his earliest rays reach our eyes; entering a denser medium, these rays bend round to meet our vision, and we actually see the body of the sun a few minutes before he has risen above the horizon—like the shilling in the basin, we see him round a corner. In proportion as the sun approaches the zenith, the refraction diminishes; and as he recedes towards setting, it increases. So considerable is it in the hazy atmosphere of the evening, that we retain a sight of his disk after he has set.

From these explanations, it will appear that the directness of our vision is at all times liable to be disturbed by atmospheric conditions. So long as the atmosphere betwixt our person and the object we are looking at is of the same density, we may be said to see in a straight line to the object; but if by any cause a portion of that atmosphere is rendered less or more dense, the line of vision is at once refracted or bent from its course. A thorough comprehension of this simple truth in science has banished a mass of superstition. It has been found that, by means of powerful refraction, objects at a great distance, and round the back of a hill, or considerably beneath the horizon, are brought into sight. In some countries, this phenomenon is called the *mirage*. The following is one of the most interesting and best authenticated examples:—In a voyage performed by Captain Scoresby in 1822, he was able to recognise his father's ship, when below the horizon, from the inverted image of it which appeared in the air. 'It was,' says he, 'so well defined, that I could distinguish by a telescope every sail, the general rig of the ship, and its particular character; insomuch that I confidently pronounced it to be my father's ship the *Fame*, which it afterwards proved to be; though, on comparing notes with my father, I found that our relative position at the time gave our distance from one another very nearly thirty miles, being about seventeen miles beyond the horizon, and some leagues beyond the limit of direct vision. I was so struck by the peculiarity of the circumstance, that I mentioned it to the officer of the watch, stating my full conviction that the *Fame* was then cruising in the neighbouring inlet.'

A curious phenomenon of this kind was seen by Dr Vince, on the 6th of August 1806, at 7 P.M. To an observer at Ramsgate, the tops of the four turrets of Dover Castle are usually seen over a hill between Ramsgate and Dover. Dr Vince, however, when at Ramsgate, saw the whole of Dover Castle, as if it had been brought over and placed on the Ramsgate side of the hill. The image of the castle was so vivid, that the hill itself did not appear through the image.

In the sandy plains of Egypt, the mirage is seen to great advantage. These plains are often interrupted by small eminences, upon which the inhabitants have built their villages, to escape the inundations of the Nile. In the morning and evening, objects are seen in their natural form and position; but when the surface of the sandy ground is heated by the sun, the land seems terminated at a particular distance by a general inundation: the villages which are beyond it appear like so many islands in a great lake, and between each village an inverted image of it is seen.

That the phenomena of the mirage are produced by variations in the refractive power of the atmosphere, can be proved by experiment. If the variation of the refractive power of the air takes place in a horizontal line perpendicular to the line of vision—that is, from right to left—then we have the lateral mirage; that is, an image of a ship may be seen on the right or left hand of the real ship, or on both, if the variation of refractive power is the same on each side of the line of vision. If there should happen at the same time both a vertical and a lateral variation of refractive power in the air, and if the variation should be such as to expand or elongate the object in both directions, then the object would be magnified, as if observed through a telescope, and might be seen and recognised at a distance at which it would not otherwise have been visible. If the refractive power, on the contrary, varied so as to contract the object in both directions, the image of it would be diminished, as if seen through a concave lens.

In order to represent artificially the effects of the mirage, Dr Wollaston suggested the viewing of an object through a stratum of spirit of wine lying above water in a crystal jar, or a stratum of water lying above one of sirup. These substances, by their gradual incorporation, produce a refractive power diminishing from the spirit of wine to the water, or from the sirup to the water: so that, by looking through the mixed or intermediate stratum at a word or object held behind the bottle which contains the fluids, an inverted image will be seen. The same effect, it has been shewn, may be produced by looking along the side of a red-hot poker at a word or object ten or twelve feet distant. At a distance less than three-eighths of an inch from the line of the poker, an inverted image is seen, and within and without that, an erect image.

The method employed by Sir David Brewster to illustrate these phenomena, consists in holding a heated iron above a mass of water bounded by parallel plates of glass; as the heat descends slowly through the fluid, we have a regular variation of density, which gradually diminishes from the bottom to the surface. If we now withdraw the heated iron, and put a cold body in its place, or even allow the air to act alone, the superficial stratum of water will give out its heat, so as to produce a decrease of density from the surface to a certain depth below it. Through the medium thus constituted, the phenomena of the mirage may be seen in the most interesting manner.

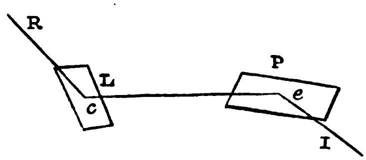
Double Refraction.

In the preceding part of this section, we have considered a single ray of light, reflected or transmitted through the substance of a transparent body, as leaving it in the same way in which it came into contact with it—namely, in a single pencil or ray. But there are a great many bodies which have the power of breaking the pencil of light incident upon their surfaces into two separate parts or pencils, more or less inclined to one another, according to the nature and state of the body, and according to the direction of the incident pencil. This is called *double refraction*, and the bodies which produce it are called doubly refracting bodies or crystals. They are very numerous, and include all salts and crystallised minerals not having the primitive forms of the cube, the regular octohedron, and the rhomboidal dodecahedron. Of all known bodies, the Iceland spar, or rhomboidal carbonate of lime, shews the fact with the greatest certainty; and as it is a mineral easily procured, it has been generally used in experiments upon this subject. Its crystals are of a rhomboidal form, having six acute solid angles, and two obtuse. Double refraction of light is employed to advantage in some kinds of lighthouses; and those who wish to investigate its nature and properties, may be referred to advanced treatises on the subject.

Polarisation of Light.

A ray of light, after reflection at a certain angle from the surface of any body, is found to have undergone a remarkable change in its nature. To the unaided eye, it

appears to possess only the attributes of ordinary light; but when certain tests are applied to it, it is found to have acquired new properties. Thus, let I*e* be a ray

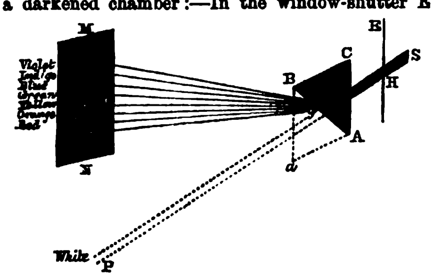


incident at an angle of 33° on a plate of glass P, and let it be reflected in the line *ec* to another plate L, so situated that the angle of incidence on it is also 33°, and that the new plane of incidence *ec*R coincides with the first I*ec*; then the light will be reflected from the second plate in the ordinary way. But if the new plane of incidence *ec*R is perpendicular to the former, there is *no light reflected.* The ray *ec* is therefore quite different from ordinary light. The ray *ec*, reflected at the first incidence, is said to be *polarised;* and the angle at which this effect happens is called the angle of *polarisation.* When light is transmitted through certain crystals, called double-refracting crystals, it is found to be similarly polarised. For further details on this part of the subject, we must also refer to works of higher scope than the present.

Colour by Refraction.

One of the most remarkable phenomena attending refraction is, that the rays of light, which seem to us to be white, may be separated into rays of various colours. It will be obvious that light has the effect of representing colours, where no colour substantially exists, by noticing the glancing and varied hues on irregular surfaces of glass, ice, or other crystallised substances.

The proper method of analysing the rays of light, and discovering into what colours they may be resolved, is to procure a prism, and perform the following experiment in a darkened chamber:—In the window-shutter E of



a darkened room, make a small hole H, through which admit a beam of the sun's light S, which, when nothing is interposed, will proceed in a straight line to P, and form a luminous white spot. If we now interpose a prism BAC, whose refracting angle is B*a*C, so that the beam of light may fall on its surface CA, and emerge at the same angle from its second surface BA, in the direction *g*G, and if we receive the refracted beam on the opposite wall, or on a white screen MN, 'we should expect,' says Sir David Brewster, 'from the principles already laid down, that the white beam which previously fell upon P would suffer only a change in its direction, and fall somewhere upon MN, forming there a round white spot exactly similar to that at P. But this is not the case. Instead of a white spot, there will be formed upon the screen MN an oblong image KL of the sun, containing seven colours—namely, red, orange, yellow, green, blue, indigo, and violet—the whole beam of light diverging from its emergence out of the prism at *g*, and being bounded by the lines *g*K, *g*L. This lengthened image of the sun is called the *solar* or *prismatic spectrum.* If the aperture H is small, and the distance *g*G considerable, the colours of the spectrum will be very bright. The lowest portion of it at L is a brilliant red. This red shades off by imperceptible gradations into orange, the orange into yellow, the yellow into green, the green into blue, the blue into a pure indigo, and the indigo into a violet. No lines are seen across the spectrum thus produced; and it is extremely difficult for the sharpest eye to point out the boundary of the different colours. Sir Isaac Newton, however, by many trials, found the lengths of the colours to be as follow, in the kind of glass of which his prism was made:—Red, 45; orange, 27; yellow, 40; green, 60; blue, 60; indigo, 48; violet, 80—Total length, 360.'

These colours are not equally brilliant. At the lower end L of the spectrum, the red is comparatively faint, but grows brighter as it approaches the orange. The light increases gradually to the middle of the yellow, where it is brightest; and from this it gradually declines to the upper or violet end K of the spectrum, where it is extremely faint.

From the phenomena which we have now described, Sir Isaac Newton concluded that the beam of white light is compounded of light of seven different colours, and that for each of these different kinds of light, the glass of which his prism was made had different indices—that is, measures of refraction; the index of refraction for the red light being the least, and that of the violet the greatest.

By means of a second prism placed behind a hole in the screen MN, opposite the centre of each coloured space, Sir Isaac Newton refracted the light a second time. In this case it was not drawn out into an oblong image as before, and was not refracted into any other colour than that which formerly belonged to each particular ray. Hence this great philosopher concluded that the light of each particular colour possessed the same index of refraction; and he termed such light homogeneous—that is, of the same kind, or simple; white light being regarded as heterogeneous—that is, of different kinds, or compound.

By various experiments, Sir Isaac proved that all the colours, when again combined, formed or recomposed white light. Indeed, the doctrine may be illustrated by mixing together, in proper proportions, seven colours as like those of the spectrum as can possibly be got. By their union a grayish white is formed, for powders of the exact tint as those of the spectrum cannot be obtained. It may also be proved in this manner:—Let a circle of paper be divided into sections of the same size, and coloured like the spaces in the spectrum, and placed upon a humming-top, which is made to revolve rapidly; the effect of all the colours, when combined, is to produce a grayish white.

'All transparent substances, in bending light,' observes Dr Arnott, 'produce more or less of the separation of colour; but it is an important fact, that the quality of merely bending a beam, or of *refraction*, and that of dividing it into coloured beams, or of *dispersion*, are distinct qualities, and not having the same proportion to each other in different substances. Newton, from not discovering this, concluded that a perfect telescope of refraction could never be made; he supposed that the bent light would always become coloured, and so render the object indistinct. We now know, however, that by combining two or more media, we may obtain bending of light without dispersion—thus, by opposing a glass which bends five degrees and disperses one degree, to another glass which bends three degrees and disperses one, the opposing dispersions will just counterbalance each other, while the two degrees of excess of bending will remain to be applied to use.' It is on this principle that achromatic lenses are constructed.

It having been found, by the experiments of Newton and others, that none of the seven colours of the solar spectrum could be broken by the prism into new colours, the theory was in some measure established that there

were *seven* primitive colours. In time, however, practical men discovered that there were only *three* simple or homogeneous colours, and that all others resulted from them. These three primitive colours were *red*, *blue*, and *yellow*. On this doctrine we give the following extract from a treatise on the *Laws of Harmonious Colouring*, by Mr D. R. Hay (Edinburgh):—

'Although this theory (that of there being only three primitive colours) was not set up in opposition to that of the natural philosophers, but seemed only to be established in a practical point of view, neither was it supported by any scientific experiments; yet it appeared to me more consistent with the general simplicity of nature, and I could not believe that she required seven homogeneous parts to produce what art could do by three. For instance, an artist can make all the colours, and indeed a correct representation of the prismatic spectrum (so far as the purity of his materials will allow), with three colours only; while, according to the theory of Sir Isaac Newton, seven simple or homogeneous colours were employed to produce the real one.

'The following discovery, made by Buffon, and illustrated by succeeding philosophers, helped to strengthen me in the conviction that the scientific theory might, like that of the practical artist, be reducible to three simple or homogeneous parts. If we look steadily for a considerable time upon a spot of any given colour, placed on a white or black ground, it will appear surrounded by a border of another colour. And this colour will uniformly be found to be that which makes up the triad: for if the spot be red, the border will be green, which is composed of blue and yellow; if blue, the border will be orange, composed of yellow and red; and if yellow, the border will be purple—making in all cases a tri-unity of the three colours called by artists homogeneous.

'With a view to throw such light upon the subject as my limited opportunities would permit, I went over the experiments by which Sir Isaac Newton established his theory, and the same results occurred: I could not separate any one colour of the solar spectrum into two. The imperceptible manner in which the colours were blended together upon the spectrum, however, and the circumstance of the colours which practical people call compound being always placed at the adjunct of the two of which they say it is composed, with my previous conviction, induced me to continue my experiments; and although I could not, by analysis, prove that there were only three colours, I succeeded in proving it to my own satisfaction, synthetically, in the following manner:—

'After having tried every colour in succession, and finding that none of them could be separated into two, I next made a hole in the first screen in the centre of the blue of the spectrum, and another in that of the red. I had thereby a spot of each of these colours upon a second screen. I then, by means of another prism, directed the blue spot to the same part of the second screen on which the red appeared, where they united, and produced a violet as pure and intense as that upon the spectrum. I did the same with the blue and yellow, and produced the prismatic green; as also with the red and yellow, and orange was the result. I tried, in the same manner, to mix a simple with what I thought a compound colour, but they did not unite; for no sooner was the red spot thrown upon the green than it disappeared.

'I tried the same experiment with two spectra, the one behind, and of course a little above the other, and passed a spot of each colour successively over the spectrum which was furthest from the window, and the same result occurred. It, therefore, appeared to me that these three colours had an affinity to one another that did not exist in the others, and that they could not be the same in every respect, except colour and refrangibility, as had hitherto been taught.

'These opinions, the result of my experiments, I published in 1828, as being a necessary part of a treatise of this nature; and I did so with great diffidence, well knowing that I was soaring far above my own element in making an attempt to throw light upon such a subject. I had, however, the gratification to learn that these facts were afterwards proved in a communication read to the Royal Society of Edinburgh by Sir David Brewster, on the 21st of March 1831, in which he also shewed that white light consists of the three primary colours—red, yellow, and blue; and that the other colours shewn by the prism are composed of these.

'The three homogeneous colours—yellow, red, and blue—have been proved by Field, in the most satisfactory manner, to be in numerical proportional power as follows—yellow, three; red, five; and blue, eight.

'When these three colours are reflected from any opaque body in these proportions, white is produced. They are then in an active state, but each is neutralised by the relative effect that the others have upon it. When they are absorbed in the same proportions, they are in a passive state, and black is the result. When transmitted through any transparent body, the effect is the same; but in the first case they are material or inherent, and in the second, impalpable or transient. Colour, therefore, depends entirely on the reflective or refractive power of bodies, as the transmission or reflection of sound does upon their vibratory powers.'

THE RAINBOW.

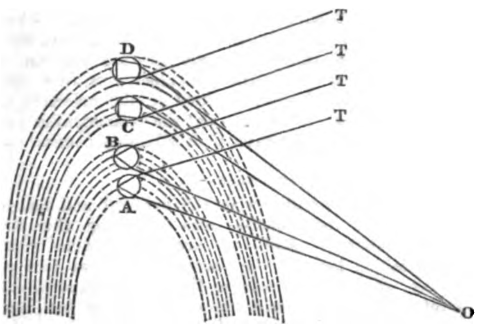
Every one is familiar with the brilliant and many-coloured arch occasionally seen spanning the sky during a shower. Rainbows are only visible when rain is falling between the spectator and that part of the sky which is opposite to the sun. The sun, the eye of the spectator, and the centre of the bow, are in a line; so that however far the sun is above the horizon, the centre of the bow must be as far below, and thus the bow is always less than a semicircle, except when the sun is just in the horizon. There are usually two bows or arches—the one inner or primary, the other outer or secondary; and within the primary rainbow, and in contact with it, and without the secondary one, there have been seen supernumerary bows.

The primary or inner rainbow, which is commonly seen alone, is part of a circle whose radius is 41°. It consists of seven differently coloured bows—namely, violet, which is the innermost, indigo, blue, green, yellow, orange, and red, which is the outermost. These colours have the same proportional breadth as the spaces in the prismatic spectrum. This bow is therefore only an infinite number of prismatic spectra, arranged in the circumference of a circle; and it would be easy, by a circular arrangement of prisms, or by covering up all the central part of a large lens, to produce a small arch of exactly the same colours. All that we require, therefore, to form a rainbow, is a great number of transparent bodies capable of forming a great number of prismatic spectra from the light of the sun.

Sir David Brewster thus explains the cause of the arc of the sky:—As the rainbow is never seen unless when rain is actually falling between the spectator and the sky opposite to the sun, we are led to believe that the transparent bodies required are drops of rain, which we know to be small spheres. If we look into a globe of glass or water held above the head, and opposite to the sun, we shall actually see a prismatic spectrum reflected from the further side of the globe. In this spectrum the violet rays will be innermost, and the spectrum vertical. If we hold the globe horizontal, on a level with the eye, so as to see the sun's light reflected in a horizontal plane, we shall see a horizontal spectrum, with the violet rays innermost. In like manner, if we hold a globe in a position intermediate between these two, so as to see the sun's light reflected in a plane inclined 45° to the horizon, we shall perceive a

spectrum inclined 45° to the horizon, with the violet innermost. Now, since in a shower of rain there are drops in all positions relative to the eye, the eye will receive spectra inclined at all angles to the horizon, so that, when combined, they will form the large circular spectrum which constitutes the rainbow.

To explain this more clearly—let AB be drops of rain exposed in the sun's rays, incident upon them in the direction TA, TB, out of the whole beam of light which falls upon the drop; those rays which pass through or near the axis of the drop will be refracted to a focus behind it; but those which fall on the upper side of the drop will be refracted, the red rays least, and the violet most, and will fall upon the back of the drop with such sufficient obliquity that many of them will be reflected, as shewn in the figure. These rays will be again refracted, and will meet the eye at O, which will perceive a spectrum or prismatic image of the sun, with the red space uppermost, and the violet undermost. If the sun, the eye, and the drops AB, are all in the same



vertical plane, the spectrum produced by AB will form the colours at the very summit of the bow, as in the figure. Let us now suppose a drop to be near the horizon, so that the eye, the drop, and the sun are in a plane inclined to the horizon, a ray of the sun's light will be reflected in the same manner as at AB, with this difference only, that the plane of reflection will be inclined to the horizon, and will form part of the bow distant from the summit. Hence it is manifest that the drops of rain immediately above the line joining the eye, and the upper part of the rainbow, and in the plane passing through the eye and the sun, will form the upper part of the bow; and the drops to the right and left hand of the observer, and without the line joining the eye and the lowest part of the bow, will form the lowest part of the bow on each hand. Not a single drop, therefore, between the eye and the space within the bow is concerned in its production; so that, if a shower were to fall regularly from a cloud, the rainbow would appear before a single drop of rain had reached the ground.

If we compute the inclination of the red ray and the violet ray to the incident rays TA, TB, we shall find it to be 42° 2′ for the red, and 40° 17′ for the violet, so that the breadth of the rainbow will be the difference of those numbers, or 1° 45′, or nearly three times and a half the sun's diameter. These results coincide so accurately with observation, as to leave no doubt that the primary rainbow is produced by two refractions and one intermediate reflection of the rays that fall on the upper sides of the drops of rain.

It is obvious that some of the rays will suffer a second reflection at the points where they are represented as quitting the drop; but these reflected rays will go up into the sky, and cannot possibly reach the eye at O. But though this is the case with rays that enter the upper side of the drop, as at AB, or the side furthest from the eye, yet those which enter it on the under side, or the side nearest the eye, may after two reflections reach the eye, as shewn in the drops DC, where the rays TT enter the drops below. The red and violet rays will be refracted in different directions, and after being twice reflected, will be finally refracted to the eye at O; the violet forming the upper part, and the red the under part of the spectrum. If we now compute the inclination of these rays to the incident rays TT, we shall find them to be 50° 58′ for the red ray, and 54° 10′ for the violet ray; the difference of which, or 3° 12′ will be the breadth of the bow, and the distance between the bows will be 8° 15′. Hence it is clear that a secondary bow will be formed without the primary bow, and with its colours reversed, in consequence of their being produced by two reflections and two refractions. The breadth of the secondary bow is nearly twice as great as that of the primary one, and its colours must be much fainter, because it consists of light that has suffered two reflections in place of one.

Many peculiar kinds of rainbows have been observed, such as lunar ones, in which, however, the colours are faint and barely perceptible. Supernumerary rainbows are sometimes seen. 'On the 5th of July 1828,' says Sir David Brewster, 'I observed three supernumerary bows within the primary bow, each consisting of green and red arches, and in contact with the violet arch of the primary bow. On the outside of the outer or secondary bow, I saw distinctly a red arch, and beyond it a very faint green one, constituting a supernumerary bow, analogous to those within the primary rainbow.'

Red rainbows, distorted rainbows, and inverted rainbows on the grass, have been observed. The latter are formed by the drops of rain suspended on the spiders' webs in the fields. It is only necessary to mention that the iris, so frequently seen overarching a cataract, is produced by the refraction of light in passing through the misty vapour generated by the falling water.

REFLECTION OF LIGHT.

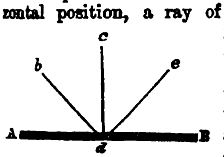
Light, as has been mentioned, is diffused around us by the refractive power of the atmosphere, and therefore objects are quite visible though the rays of the sun do not strike directly upon them; in plainer terms, the atmosphere may be compared to the thick piece of glass called a *bull's eye* fixed in the deck of a ship, by which rays of light are collected and dispersed into all corners of the apartment beneath. The atmosphere being thus a vehicle of light, it may be supposed that, if we were to ascend to a great height above the level of the earth, or beyond the sphere of the atmosphere, we should be almost in darkness, although we were in reality nearer the sun. There is reason to believe that such would be the case; for travellers who have ascended to the summit of Mont Blanc, or about 15,000 feet above the level of the sea, mention that at that height the sky appears to be of an exceedingly dark-blue colour, or almost black, and the light so faint that the stars are visible. We may understand from this, that the rays of the sun travel through immense regions of darkness before they reach our atmosphere, and are diffused into that universal soft light which we observe around us.

But besides being diffused by a pure atmospheric medium, light is greatly increased in brilliancy by *reflection*. If all the objects on the surface of our planet were to be black, which is a negation of all colour, the sun's light would be absorbed, or the objects would return no part of the rays which fell upon them; and we should, even while the sun shone, possess much less light than we now enjoy. Nature has avoided this calamity, and by producing all varieties of colours in objects, the sun's rays which fall upon them are less or more reflected, or sent back into the general mass of light. We now, then, understand that every object we see reflects rays of light, and that these rays travel from the object to our eye, as soon as we bend our vision upon it: inasmuch, however, as a thousand or more individuals may see the same object at the same instant

of time, it is evident that the rays emanate at all points, and fall upon eyes at every variety of angle.

If the object be clear or polished in its surface, it will possess the power of representing the image of objects whose rays fall on it. Thus the surface of a smooth lake will represent the image of the sky above, or the neighbouring hills, or of any object floating on its surface. This natural property in clear surfaces has suggested the formation of mirrors or looking-glasses. A mirror, or *speculum*, as it is scientifically called, is any instrument of a regular form, employed for the purpose of reflecting light or forming images of objects. Mirrors usually consist of metal or glass, having a highly polished surface. Those which are constructed of glass are coated upon the back with quicksilver, or rather with tinfoil mixed with a little mercury, for the purpose of reflecting more light: were this not the case, so little light would be thrown back, on account of glass transmitting it to a considerable extent, that a very indistinct image would be formed. The word speculum is generally confined to metallic mirrors, and they are either plane, concave, or convex. The plane ones are perfectly flat, like a looking-glass; and a common watch-glass conveys a very good idea of the other two species of mirrors. Coat the hollow surface with mercury, and place it before a candle—it forms a convex mirror; coat it upon the other side, and employ it as before—it becomes a concave mirror.

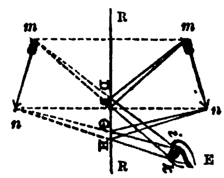
If a plane mirror AB be placed exactly in a horizontal position, a ray of light *c* darting downwards in an exactly perpendicular direction, and striking it at *d*, will be thrown back in the exact path which it traversed in its descent, without any deviation. If, however, it descends in an oblique manner, as is shewn at *e*—a point midway between the perpendicular *c* and the horizontal AB—it will not return, as in the former instance, to the place whence it came, but will be reflected from the mirror at an angle exactly equal to that at which it descended upon it. The ray *ed* is called the *incident* ray, and *db* the *reflected* ray. In the figure, *edc* is called the *angle of incidence*, and *bdc* the *angle of reflection;* and they are, as we have observed, exactly equal to each other. The one, then, can in all cases be inferred from the other. This holds true whatever shape the mirror may be of—plane, concave, or convex—and whatever number of rays may fall upon it.



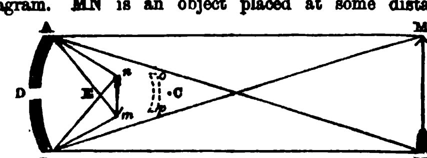
Let us apply the principle here mentioned to the simple phenomenon of seeing ourselves in a plane looking-glass. When we stand directly in front of a mirror, we see our image represented in it; and as we move, so does the image appear to move also, but with a peculiarity in its motion: if, for example, we walk towards the mirror, the image is seen to approach in a similar manner, but the approach is with double the velocity, because the two motions are equal and contrary. Suppose, however, while we stand at the glass, another person walks up behind us, his image will appear to us to move at the same rate as he walks, though to him the velocity will seem double, because, with regard to us, there will be but one motion, and with regard to him there will be two equal and contrary motions.

In the case of standing directly in front of the mirror, the image is necessarily before us, for the rays proceeding from our eye to the mirror are sent back from the surface without any angle of incidence. The case is otherwise when we stand so far at a side that we cannot see ourselves in the glass, though we can see the image of another person equally far off on the opposite side. Two persons so situated will see each other though they cannot see themselves, because the line of rays from the first person striking on the glass form an angle of reflection, and dart off in the direction of the second person, while the rays from the second person are similarly reflected towards the first. Such is a practical exemplification of the angle of reflection in mirrors.

The principle of reflection may be more minutely explained as follows:—We suppose RR to be the surface of a plane mirror, the arrow MN any object placed in front of it, and E the eye of an observer placed at *ik*. Of the rays which shoot in a rectilinear direction from the points MN of the object, and are reflected from the mirror, those which enter the eye are few in number, and must be reflected from portions DF and GH of the mirror, so situated with reference to the eye and the object, that the angles of incidence of the rays which fall on these portions must be equal to the angles of reflection of those which enter the eye between *i* and *k*. For instance, the ray MD is reflected in the direction D*i*, and the ray MF in the direction F*k*. In the same manner, the rays NG and NH will be reflected severally in the directions G*i* and H*k*. If the rays *i*D and *k*F be continued backwards, they will meet at a point *m*, whence they will appear to have come to the eye. For the same reason, the rays G*i* and H*k*, if continued in the same manner, will seem to meet at the point *n* as their focus, and *mn* will be the virtual image of the object MN. It is called *virtual*, because it is not formed by the actual union of rays in a focus, and cannot be received upon paper. The virtual image *mn* is as far behind the mirror as the object MN is before it; consequently, if we join *mn*, it will be of the same dimensions as MN, and have the same position behind the mirror as the object has before it. If we join the points M*m* and N*n* the lines M*m* and N*n* will be perpendicular to the mirror RR, and consequently parallel. In every position of the eye the image is seen in the same spot; its absolute size is always the same, and its apparent size is also the same when seen at equal distances from the eye. If the object MN is an individual surveying himself in the mirror, he will see his perfect image as if at *mn*.



The manner in which rays are reflected from a concave mirror, next deserves our attention. It will have been frequently observed by the reader, that when he looked at himself in the hollow of a polished metal spoon, his face and bust appeared to be inverted, or upside down. We explain this by referring to the accompanying diagram. MN is an object placed at some distance



from a concave mirror AB, whose centre is C, and whose principal focus is E. The rays from M fall diverging upon the mirror, and are reflected to a focus at *m* (a little without the principal focus), where they form an image of the extremity M. In the same way, a representation of the extremity N will be painted at *n*, so that a complete but inverted image of NM will thus be formed; and it is evident that it will be very bright, though small, because a great number of rays are concentrated, and concur in forming each point of the image. The size of the image thus formed corresponds to the distance of the object from the mirror. If the latter be large, and the former very bright, a series of beautiful experiments may be made by varying the distance of the object, and observing the variations in the size and place of the image. As the object recedes from the mirror, the picture approaches E, and gradually decreases in size.

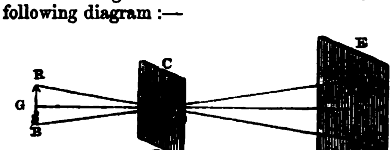
If we consider *mn* as a small object, a magnified

representation of it will be formed at MN, which, when viewed by a convex lens, such as will be afterwards described, constitutes a *reflecting microscope.* If we place a small concave mirror *op* behind it, so as to enlarge the image, and reflect the rays through an opening D in the large mirror AB, then this second image may be magnified still more by means of a lens, in which case it constitutes a Gregorian reflecting telescope. If instead of a concave we employ a convex mirror *op*, and place it between E and *nm*, so as to reflect the rays which would otherwise have met at *nm*, then an enlarged image would in this case also be painted at D, where it can be magnified as in the former instance.

An image formed by a concave mirror is always highly magnified when the object is near the focus; but as it passes that point, and approaches the mirror, the image gradually decreases in size, and becomes equal to the object when the latter touches the mirror. Indeed, when the object is placed between the principal focus and the mirror, the image is a virtual one apparently formed behind the mirror, or would be so formed behind it if the substance of the mirror permitted. Concave mirrors, from their property of converging rays into a focus, may be used as burning-glasses; practically, mirrors of this shape are used to gather the rays from lamps, and reflect them, with increased brilliancy, into the darkness. The lamps of coaches, light-houses, &c., are fitted up with these reflectors.

With respect to convex mirrors, they always form images of a diminished size, because the rays which form them become convergent in their passage to the eye of the spectator; in other words, the rays from the object proceed to a virtual or imaginary focus behind the mirror, and thence the image, in a miniature form, seems to be reflected to the eye. In this, as in all cases of reflection from concave mirrors, the size of the image represented is exactly what it might be expected to be if we could see through the glass, and observe the dimensions at the virtual focus.

It is perhaps not generally known that images may be formed upon a piece of paper, by placing a small hole between the object and the paper, and excluding all extraneous light. This will be best understood by the following diagram:—

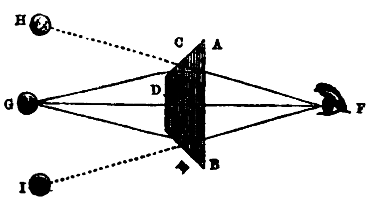


Let CD be a window-shutter having a small aperture A, and EF a piece of paper placed in a dark chamber. Then, if an illuminated object RGB is placed on the outside of the shutter, we shall observe an inverted image of this object painted on the paper at *rgb*. In order to understand how this takes place, let us suppose the object RGB to have three distinct colours—*red* at R, *green* at G, and *blue* at B; then it is plain that the *red* light from R will pass in straight lines through the aperture A, and fall upon the paper EF at *r*. In like manner, the *green* from G, and the *blue* light from B, will severally fall upon the paper at *g* and *b*, and an inverted image *rgb* of the object RGB will be painted upon it. Every coloured point in the object RGB having a coloured point corresponding to it, and opposite to it, on the paper EF the image *bgr* will be an accurate picture of the object RGB, provided the aperture A is very small. If it be increased in size, indistinctness in the image will ensue; for with a large aperture, two adjacent points of the object will throw their light on the same point of the paper, and thus create confusion in the picture. It is perfectly clear that if the paper EF be moved to a further distance from the hole A, the size of the image will be increased; and if it be brought nearer to it, it will be diminished.

LENSES.

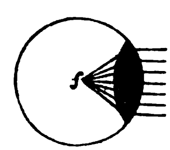
Lenses, as already mentioned, are of different forms, and consequently possess different refractive powers. A lens may be composed of any transparent substance —as glass, diamond, a globule of water, &c.; in the arts, a lens is made of glass, as pure and colourless as possible. The design in forming lenses is to procure a medium through which the rays of light from any object may pass, and converge to a corresponding point beyond. The manner in which the rays proceed through the glass, and then centre in a focal point, will depend on the form of the lens, its capacity for refraction, and the distance of the object.

If we take a piece of glass, flat on one side, and cut into different faces on the other, and then look through it from the flat side at any object—for instance, a pea, we shall see as many peas as there are faces receiving the rays from the single pea. We may exemplify this principle of multiplication by the following figure, in which AB is a lens flat on one side, and cut into three faces on the other CDE. F is the eye of the spectator, and G the pea to be looked at. The eye receives a pencil of rays direct through the lens at D, and sees the object without refraction. A pencil also proceeds from

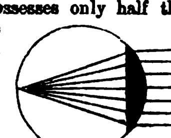


G to the face C, and another pencil to the face E, and in both cases the rays are bent and refracted to the eye. This eye, however, does not recognise the path of either of these oblique rays, but perceives the image of a pea at H and at I; and thus three peas seem to be seen in place of only one.

In smoothly ground lenses, in which there are no distinct faces to multiply the images of an object, the rays bend, as we have said, so as to meet in a corresponding point beyond them. A lens may consist of a perfect globe of glass, or globe filled with pure water, in which case the refractive power will be considerable; a double convex lens, which is the more common kind, may be viewed as a portion cut out of the side of a sphere, as seen in the annexed fig.

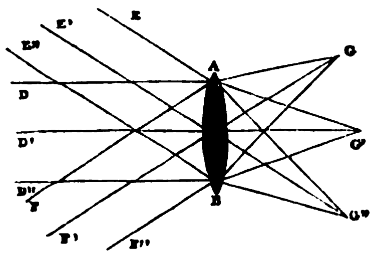


Here, as in all such cases of convexity, the focus of the parallel rays passing through the lens is at *f*, which is the centre of the sphere of which the further or anterior side is a portion or a point at half the diameter, or *radius*, of the sphere from it. Should we take a plano-convex lens, the focal point would be considerably different. In the next figure we have an example of this kind of lens, which evidently possesses only half the refractive power of the double convex glass.



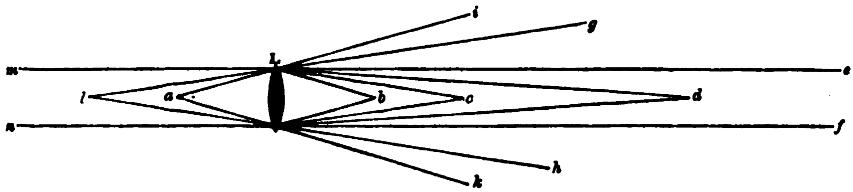
Here the parallel rays, falling on the convex side of the lens, are seen to converge at the distance of the whole diameter of the sphere. Thus the focal point at which the rays of light fall is always regulated by the degree of curvature of the lens. We shall illustrate this by various diagrams, to which we ask the reader's careful attention, for the subject is somewhat difficult, and cannot be comprehended by a superficial glance.

We take a double convex lens represented by AB, the axis of which is the line G'CD'. The ray D'G', being straight through the centre, suffers no refraction;



but the rays DA and D"B are refracted so as to meet at the focal point G'. We now observe that the parallel rays EA, E'C, and E"B, and also FA, F'C, and F"B, falling obliquely on the lens, will in a similar manner be refracted, and have their foci at G and G", at the same distance from the lens. Those lines which pass through the centre—as E'CG" and F'CG—do not alter their direction, not being refracted. Thus, in whatever way parallel rays pass through a lens, we have a focal point beyond it, be it straight forward or in an oblique direction.

The distance at which the rays meet beyond the lens is exemplified in the next diagram, given by Dr Arnott in his treatise on Physics, and whose definition of the focal point we beg leave to offer:—'Rays falling from *a* on a comparatively flat or weak lens at L, might meet only at *d*, or even further off; while with a stronger or more convex lens, they might meet at *c* or at *b*. A lens weaker still might only destroy the divergence of the rays, without being able to give them any convergence, or to bend them enough to bring them to a point at all, and then they would proceed all parallel to each other, as seen at *e* and *f;* and if the lens were yet weaker, it might only destroy a part of the divergence, causing the rays from *a* to go to *g* and *h*, after passing through, instead of to, *i* and *k*, in their original direction.



'In an analogous manner, light coming to the lens in the contrary direction from *bcd*, &c., might, according to the strength of the lens, be all made to come to a focus at *a* or at *l*, or in some more distant point; or the rays might become parallel, as *m* and *n*, and therefore never come to a focus, or they might remain divergent.

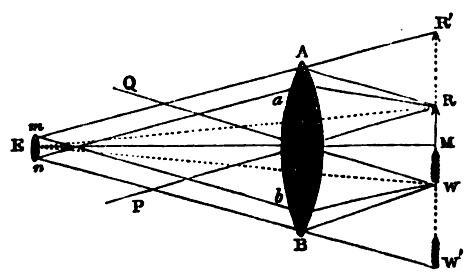
'It may be observed in the above figure that the further an object is from the lens, the less divergent are the rays darting from it towards the lens, or the more nearly do they approach to being parallel. If the distance of the radiant point be very great, they really are so nearly parallel that a very nice test is required to detect the non-accordance. Rays, for instance, coming to the earth from the sun do not diverge the millionth of an inch in a thousand miles. Hence, when we wish to make experiments with parallel rays, we take those of the sun.

'Any two points so situated on the opposite sides of a lens, as that when either becomes the radiant point of light, the other is the focus of such light, are called *conjugate foci*. An object and its image formed by a lens must always be in *conjugate foci;* and when the one is nearer the lens, the other will be in a certain proportion more distant.

'What is called the *principal* focus of a lens, and by the distance of which from the glass we compare or classify lenses among themselves, is the point at which the sun's rays—that is, parallel rays—are made to meet; and thus, by holding the glass in the sun, and noting at what distance behind it the little luminous spot or image of the sun is formed, we can at once ascertain the focus of a glass as at *a* for the rays *e* and *f*.'

If a convex lens, with a focal length less than the distance of distinct vision, is placed between the eye and an object situated in the focus of the lens, the rays of each pencil proceeding from any point in the object will emerge parallel, and an image of it will be seen distinct and *magnified*. 'The size of the image will be to that of the object as the distance of distinct vision to the focal length of the lens.'

The cause of the parallelism of the emergent rays and of the enlargement of the image may be thus explained: Let E be the eye, and *mn* the diameter of its pupil, and RW a small object placed at the least distance of distinct vision. When the lens AB is placed so that RW is in its focus, the conical pencil of rays proceeding from any point R, having the first surface of the lens for its base, will, after passing through the lens, emerge in a cylindrical pencil parallel to the central ray RCP, or the axis of the incident conical pencil; but only a small portion of the refracted pencil—namely, the small pencil *Amna*—will fall on the pupil and enter the eye, and form on the retina an image of the point R. Now this point will be seen in the direction of the point *mA*, or at R'; in like manner, the other extremity W will be seen at W', and the points intermediate to R and W will have

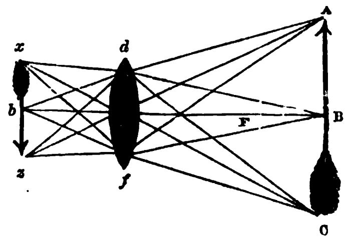


images intermediate between R' and W'. Thus the whole image will exceed the object in the proportion of R W' to RW; but these lines are to one another as EM to CM, or as the distance of distinct vision to the focal length of the lens.

The visual angle REW would be to the angle R'EW' nearly as RW to R'W'; so that the visual angle is enlarged in the ratio of the distance of distinct vision to the focal length of the lens. A convex lens, from the property it possesses of enlarging the apparent size of objects, is called a *magnifying-glass* or a *single microscope*.

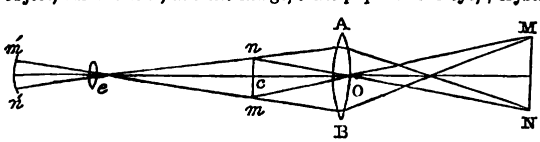
An object may be magnified on a different principle, by using a lens whose focal length exceeds the distance of distinct vision. It is evident from the preceding article, that when the focal length is equal to this distance, the image is of the same size as the object. Let now the focal length exceed this distance, and let an object AC be placed beyond F, the principal focus; it

will form an image xbz, which may be seen as if it were a real object, by an eye placed at the distance of distinct



vision; for rays proceed from points in the image just as if it were a real object, only not in all directions. The image of the point A will be at z, of B at b, and of C at x. These conjugate foci are computed by the rules formerly laid down. The image is necessarily *inverted*. If the object AC is very distant compared with the focal length of the lens, then the distance of the image from the lens will be very nearly its focal length, and the magnifying power will be determined thus:—'As the least distance of distinct vision is to the focal length of the lens, so is the apparent size of the object seen by the naked eye to its apparent size seen by means of the lens.'

The proof of this theorem is as follows:—MN is the object, AB the lens, mn the image, e the pupil of the eye,



and $m'n'$ the image on the retina of the eye. The object MN being distant, the image mn will be nearly in the principal focus of the lens AB, so that Oc is its focal length. The apparent magnitude of the object, if seen by an eye placed at O, would be measured by the angle MON; and as Oe, the sum of the distance of distinct vision ec and cO, is small compared with OM, the distance of the object, the angle MON may be considered as the visual angle of the object seen by the unaided eye. Now, the angle nem formed at e by the crossing rays ne, me, is the visual angle of the image mn; hence the apparent size of the object compared with that of its image is as those visual angles—that is, as the angle MON or mOn to men. But these angles are as their halves—namely, the angles cOn, cen, which, from the properties of a triangle, are as the opposite sides ne and nO, or very nearly as ce and cO; but ce is the distance of distinct vision, and cO the focal length of the lens; hence the theorem is as stated above.

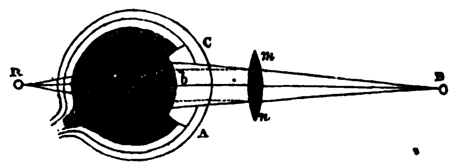
Example.—Let ce be 8 inches, and cO 32 inches; then the apparent size is increased in the ratio of 8 to 32, or 1 to 4; or the magnifying power is 4.

THE EYE—VISION.

Having, in our ACCOUNT OF THE HUMAN BODY, described the anatomical construction of the eye, we shall here confine ourselves to the actual process of vision. As mentioned in the article referred to, the eye, in front, consists of the *iris*, or variously coloured ring, which has the property of contracting or expanding to regulate the admission of light through the little dark spot in the centre called the *pupil*. Immediately behind the iris and pupil, there is a transparent substance resembling in shape a double convex glass, which is thence called the *crystalline lens*. The use of this lens is to collect and refract the rays of light, so that they may converge to a point beyond; in other words, cause them to fall on the back part of the eye, called the *retina*. Such are the main instruments of vision; and the sense of seeing is produced by certain nerves which convey intelligence of the image on the retina to the brain. If these nerves be injured, the image will still be pictured on the retina, but the mind will possess no power of recognising their presence.

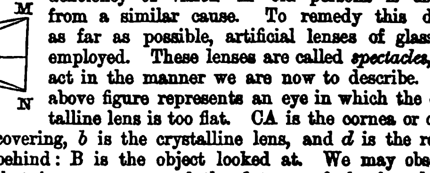
It will be understood from these explanations that the main instrument of vision is the crystalline lens, which collects the rays, and brings them to a focus on the retina. If the lens be perfectly transparent, and of the proper convexity, the light is enabled to act with due effect on the retina, and the representation of the object looked at will be correctly pictured to the mind. But if the transparent coating of the eye be dull, or the lens be either too flat or too convex, every object will appear dim.

Two kinds of defective vision are more common than any other, and they are known by the name of



long-sightedness and *short-sightedness*. Long-sightedness, or the power of seeing objects best at a considerable distance, is caused by too great a flatness in the crystalline lens and outer coating of the eye; and the deficiency of vision in old persons is usually from a similar cause. To remedy this defect as far as possible, artificial lenses of glass are employed. These lenses are called *spectacles*, and act in the manner we are now to describe. The above figure represents an eye in which the crystalline lens is too flat. CA is the cornea or outer covering, b is the crystalline lens, and d is the retina behind: B is the object looked at. We may observe, that in consequence of the flatness of the lens b, the rays proceeding from the object are not sufficiently refracted, but proceed to a focus as far back as R; in other words, the focus would be at R, if the retina would permit; but as the retina is in the way, the rays, from not being focalised upon it, cause imperfection in the vision. To remedy this, we interpose an artificial convex lens, or glass of a pair of spectacles mn, and by its aid the rays, represented by dotted lines in the figure, are brought to a focus on the retina at d. Thus, by selecting spectacles of a proper focalising power in relation to the eyes, one kind of imperfect vision is very happily remedied.

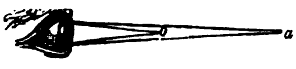
Short-sightedness arises from a cause the reverse of that just alluded to, being produced by too great a degree of convexity in the crystalline lens and cornea. In this case the rays come to a focus too soon within the eye, and do not reach the retina, unless the object



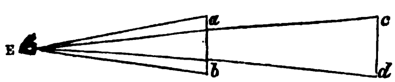
is brought quite close to the organs of vision. We here offer a representation of this condition. In consequence of the projecting globularity of the cornea CA, and the too great refracting power of the crystalline lens, the rays from the object B fall short of the retina at R. To remedy this, we interpose a double concave lens LL, by which the rays are rendered more divergent before they reach the eye, and are brought to a focus, where they should be, on the retina.

We have said above, that in short-sighted persons the

rays do not reach the retina unless the object is held close to the eyes. The effect produced by this is similar to that of employing concave spectacles; because the nearer we hold an object to our sight, the angle of the rays from it is the wider; the rays are more expanded before they enter the eye—that is, more divergent. Thus the extreme rays from a point to the pupil of the eye make a greater angle at *o*, than those from a point of a more distant object make at *a*; that is, the rays from *o* are more divergent on entering the eye than the rays from *a*, and thus nearness of an object is equivalent to seeing it at a greater distance through a concave lens. So when the object *a* is further distant than *o*, the rays from *a* have a less divergence, which is equivalent to viewing it at a nearer distance with a convex lens. These remarks, however, refer merely to the distinctness of the vision, and not to the apparent size of the object.



The apparent magnitude of the same object when viewed at different distances, depends on the size of what is called the *visual angle*—that is, the angle formed at the eye by the rays from the extremities of the object. We may exemplify this as follows:—



An eye, E, is looking at an object *ab*, and another object *cd*, of the same size, at double the distance. It is evident that the rays from *ab* are more expanded, or cause a larger angle on the eye, than the rays from *cd*. Various familiar phenomena are explained from the law of the visual angle under which an object is seen; the apparent size being less always in proportion as the distance of an object is greater. Hence the principles of perspective in drawing, by which objects are made to appear at a great distance in the background of a picture, although in reality they are as far forward as the objects in front.—(See DRAWING AND PERSPECTIVE.)

Another important circumstance connected with vision requires to be noticed. In consequence of the refractive power of the crystalline lens, the rays from an object fall upon the retina in such a manner that the image is there pictured upside down; and this inversion of the real appearance of things requires to be corrected by an act of the mind under the influence of experience. We beg leave to offer Dr Arnott's explanations on this somewhat puzzling point:—'Because the images formed on the retina are always inverted as respects the true position of the objects producing them—just as happens in a simple camera obscura—persons have wondered that things should appear upright, or in their true situations. The explanation is not difficult. It is known that a man with a wry neck judges as correctly of the position of the objects around him as any other person, never deeming them to be inclined or crooked, because their images are inclined in relation to the natural perpendicular of his retina; and that a bedridden person, obliged to keep his head upon his pillow, soon acquires the faculty of the person with wry neck; and that boys who at play bend themselves down to look backwards through their legs, although a little puzzled at first, because the usual position of the images on the retina is reversed, soon see as well in that way as in any other. It appears, therefore, that while the mind studies the form, colour, &c., of external objects in their images projected on the retina, it judges of their position, not by the accidental position of the images on the retina, but by the direction in which the light comes from the object towards the eye, no more deeming an object to be placed low because its image is low in the eye, than a man in a room into which a sunbeam enters by a hole in the window-shutter deems the sun low because its image is on the floor. A candle carried past a keyhole throws its light on the opposite wall, so as to cause the luminous spot there to move in a direction the opposite of that in which the candle is carried; but a child is very young indeed who has not learned to judge at once of the true motion of the candle by the contrary apparent motion of the image. A boatman, who, being accustomed to his oar, can direct its point against any object with great certainty, has long ceased to reflect, that to move the point of the oar in some one direction, his hand must move in the contrary direction. Now the seeing things upright, by images which are inverted, is a phenomenon akin to those here reviewed.'

The same able writer on physics thus explains another peculiarity in visual arrangements—namely, why, from having two eyes, the object does not appear to us to be double: 'In answer to this, we shall only state the simple facts of the case. As in two chess-boards there are corresponding squares, so in the two eyes there must be corresponding points, and when on those points a similar impression is made at the same time, the sensation or vision is single; but if the impression be made on points which do not correspond, owing to some disturbance of the natural position of the eyes, the vision becomes double. Healthy eyes are so wonderfully associated, that from earliest infancy they constantly move in perfect unison. By slightly pressing a finger on the ball of either eye, so as to prevent its following the motion of the other, there is immediately produced the double vision; and tumours about the eye often have the same effect. Persons who squint have always double vision, but they acquire the power of attending to the sensation in one eye at a time. Animals which have the eyes placed on opposite sides of the head, so that the two can never be directed to the same point, must possess this faculty in a more remarkable degree.

'The corresponding points in the two eyes are equidistant, and in similar directions from the centres of the retinæ, which centres are called the *points of distinct vision*, and at them the imaginary lines named the axes of the eyes terminate; but it is worthy of remark that these points, in being both to the right or both to the left of the centres, must be one of them on the inside of the centre, as regards the nose, and the other on the outside—that is to say, a point of the left eye between the centre and nose has its corresponding point in the right eye between the centre and the cheek—and from this fact arise consequences meriting attention. When the two eyes are directed to any object, their axes meet at it, and the centres of the two retinæ are opposite to it, and all the other points of the eyes have perfect mutual correspondence as regards that object, giving the sensation of single vision; but the images formed at the same time, of an object nearer to or further from the eye than the first supposed, cannot fall on *corresponding* points; for an object nearer than where the axes meet, would have both its images on the outsides of the centres, and an object more distant would have both its images on the insides of the centres—and in either case the vision would be double. Thus if a person hold up one thumb before his nose, and the other in the same direction, but further off, by then looking at the nearest, the more distant will appear double, and by looking at the more distant, the nearest will appear double. The reason for applying the term "point of distinct vision" to the centre of the retina, is felt at once by looking at a printed page, and observing that only the one letter to which the axis of the eye is directed is distinctly seen; and consequently that, although the whole page be depicted on the retina at once, the eye, in reading, has to direct its centre successively to every part.'

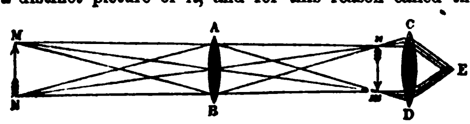
The retina of the eye possesses such exquisite sensibility, that it retains the impression of the image of any bright object presented to it for the space of the eighth of a second after the object has been withdrawn, or after the eye has been shut. Thus the burning end of a

rapidly whirled stick will appear to form hoops of fire; and a fiery meteor or sky-rocket shooting rapidly through the air, will appear as a long line of light.

The optical portion of the eye reveals nothing but surfaces variously extended and coloured. It requires experience to judge of the distance, size, solid shape, and other qualities of the objects painted on the retina. The greater part of what we think we see, we only *infer*. It has been shewn by Professor Wheatstone that the vivid conception we have of solid forms arises from the conjoint action of the two eyes upon one and the same body. Since the eyes are some distance apart from each other, if they are directed upon any object they will see different faces of it—the right eye will see one aspect or surface, and the left eye will see a different aspect, as if viewed from a point to the left. Now, the coalition of the two aspects, or the embrace of the object between the two glances, has the effect of giving a distinct and strong impression of solidity—an effect which has been imitated by Professor Wheatstone by means of an instrument called the *stereoscope*, where two different views or drawings of an object, taken from points a little apart, are made by mirrors to be viewed by the two eyes separately. At the moment the two images coincide in the view, or cover one another, a solid body seems instantaneously to start out, and the illusion of the perspective is complete.

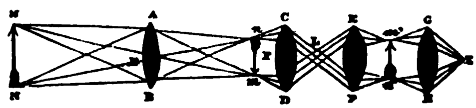
OPTICAL INSTRUMENTS.

Telescopes.— Telescopes, sometimes called spying-glasses, are instruments in the form of tubes, fitted up with lenses of different kinds and powers, and used for examining distant objects. The word telescope is derived from two Greek words signifying *afar off*, and *to see*. A telescope, in its simplest construction, contains two lenses—one is used to create a picture of the object looked at, and therefore called the *object-glass;* the second to magnify that picture, or, more properly, to enable the eye to come very close to it, and yet have a distinct picture of it, and for this reason called the



eye-glass. Two convex lenses properly adjusted, as above, constitute the simplest form of the telescope. Let the arrow MN stand for any outward object, and let its rays fall upon a convex lens AB, which is seen edgeways in the figure. The rays will be all bent, so that, at a certain distance on the other side of the lens, a new representation of the arrow *nm* will be made. The rays from the point of the arrow at M will be so acted on at the two surfaces of the lens, that they will all come together again, and make, as it were, an arrow-point at *m*. The rays from the feather at N will fall into their places at *n*, in a new arrow-head; and so on throughout, the whole being inverted. A second lens CD is used, not to form a second picture (as it would do if distance were allowed it), but to enable the eye at E to look closer at *nm* than it could otherwise do. What the eye sees, therefore, by the two lenses, is a near picture of the original arrow turned upside down. This picture is nearer and larger to the sight in proportion to the roundness of the magnifying lens. Suppose the image *nm* is six inches from the picturing or *object* lens, then if the eye look at it at a distance of six inches, the picture will have the same apparent size as the original, and nothing will be gained. But if the second lens, or *eye-piece*, enables the eye to come within one inch of the picture, and yet see it without confusion, it will be thirty-six times as large to appearance as the original—six times each way. In fact, the view is now improved as much as if a six-mile object were brought within one mile. Now, the greater the distance of the picture from the object-lens which forms it, the greater its focal distance; and the nearer that the eye can be brought to the picture by the eye-lens, the larger the appearance will be, or the greater will be the magnifying power of the telescope. Two such lenses shut up in a tube make what is called the *astronomical telescope*. In looking at the heavens, the inversion of the picture causes no inconvenience.

For land-objects, which must appear erect, a telescope is formed with additional lenses, which make a second picture, as in next fig. The lens AB makes the first picture, and the two lenses CD and EF cross the rays



again, and make a second picture, which is upright. This is viewed by the eye-piece GH. To increase the power of these telescopes, the object-glass AB is made with a very long focus, or so as to form its picture as far off from itself as possible. This requires its shape to be very much flattened, and still to preserve a perfect roundness—a matter difficult of execution. All lenses are more or less imperfect; that is, the picture they form is liable to be somewhat confused, which takes off from the advantage of the instrument. The greatest evil is one that cannot be cured by a single lens—that is, the fringing or colouring of the picture. But this action has been done away with by using a double lens, or two lenses of different kinds of glass joined together. The difference in the quality of the glasses to produce colour is so managed that they neutralise one another; and a picture free from coloured and indistinct edges is produced. This compound lens is called *achromatic*, or wanting in colour. With these lenses very perfect telescopes are made of two, three, six, or ten feet in length, and with eye-pieces of half or quarter of an inch, and under, of focal distance. A three-feet telescope—that is, a telescope where the picture is made thirty-six inches from the object-glass, and an eye-piece that lets the picture come within half an inch of the eye (a half-inch eye-piece)—would magnify seventy-two times each way, and have the same effect as if the distance of the original were divided by seventy-two. This and other instruments in which refracting lenses are employed, are called *refracting telescopes*, and they magnify or bring near in proportion as the focal distance of the object-glass is greater than the focal distance of the eye-glass.

Refracting telescopes require to be of considerable length where much power is required, and on that account reflecting telescopes are for many purposes preferred. The *reflecting telescope* was invented by Sir Isaac Newton, but has been much improved since his time. A view of the improved instrument is given beneath. The peculiarity of this instrument is, that the

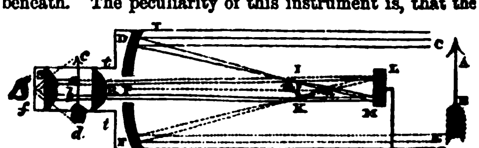
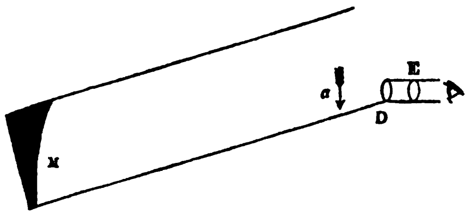


image of the object is reflected from a concave mirror within the tube, and this image is again reflected from a small mirror to the eye. Referring to the figure, T is the tube, and AB the object to be represented. At the end opposite from the object, there is a small tube *tt*. At the main end of the wide tube, there is a concave mirror DF, with a hole in the middle at P. The principal focus of this mirror is at IK; here the image *m* is inverted, and the rays, crossing each other at *n*, go on to the small reflector LM. From this they are reflected in parallel lines through the hole P. At P they enter the plano-convex lens R, which causes them to converge at *ab*; but here the

image requires to be magnified, which is done by means of the plano-convex lens S; in other words, the object is seen under the angle *cfd*. In order to accommodate focal distances, the small mirror L can be removed to a greater distance or brought nearer, by the rods and screws communicating from S.

Sir William Herschel got over the difficulty of placing the observer out between the object and the mirror, by a simpler arrangement. He gave the mirror M at the bottom of the tube a slight slope, so that



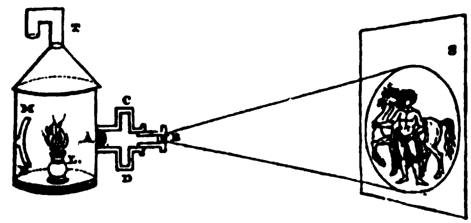
it sends its image to *a*, at the edge of the tube's mouth, where it is viewed by the eye-piece E without bringing the observer's head between the thing viewed and the mirror. On this principle he constructed telescopes of gigantic dimensions and power. His greatest was forty feet long, and the mirror four feet wide. The use of a large mirror is to take in more light, which is apt to fail in using high magnifying powers. With an eye-piece of an inch focus, the power of such a telescope would be 480 each way, which would magnify a surface nearly a quarter of a million of times. The moon would be seen by such a power, as if she were brought within 500 miles of us, her real distance being 240,000.

But Lord Rosse has surpassed Herschel in the construction of reflecting telescopes. The chief difficulty in making monster telescopes (apart from the stupendous machinery for supporting and moving them) is the forming of the mirror or speculum, which is of metal, and requires to have a surface of high polish and reflecting power, and at the same time to be ground into a perfectly spherical or rather parabolic form: the mixing of the ingredients to make a good shining metal, and the casting of an immense mass, like a millstone, of an even hardness throughout; and, lastly, the grinding, shaping, and polishing of the surface, make a series of operations of the utmost difficulty. After succeeding in the manufacture of the speculum, Lord Rosse has gone on to construct two telescopes of immense power—the one twenty-six feet long; the other, 'the monster telescope,' fifty-six feet, the focal length of the mirror being fifty-two feet. The fifty-six feet tube is seven feet wide; the mirror at the bottom is six feet wide, with a glittering polish all over the surface, and weighs three tons. This telescope is said to bear a power magnifying of more than 5000 diameters.

Microscope is a term compounded of two Greek words, signifying *small*, and *to see*, and denotes that instrument employed to examine minute objects. Those microscopes of greatest power, and termed compound, approach to the telescope in their form. The difference lies in this, that whilst in the telescope the object-glass forms the image of a distant object just as much smaller than itself as the distance of the image from the glass is less—in the microscope, conversely, a small object, placed near the focus of the object-glass, produces a more distant image, as much larger than itself as the image is more distant. In both cases, an appropriate eye-glass is employed. The object-glass of a microscope is in general very small, that of a telescope large. An object-glass of a microscope having one-eighth of an inch of focal distance, and so placed as that the image of the object is formed at six inches, the image will be of a diameter forty-eight times as great as the object; and when viewed through an eye-glass of half an inch focus, it will appear magnified twelve times more, or will appear 30,000 times larger than the object. A single or one-lens microscope magnifies chiefly by allowing the eye to see the object nearer than it could do without the glass.

A *Camera Obscura*, or *Dark Chamber*, is formed by placing a convex lens in an aperture made in the window-shutter of a darkened room. A glass of proper size and focal distance is chosen, and a screen, or the wall of the chamber, is properly prepared to receive the light; and by this means there is painted on it an accurate picture of all the objects seen from the window, everything bearing an exact resemblance to the reality.

The Magic Lantern.—When a small object is placed close to a lens, and the image reflected upon the wall of a dark chamber, at, say, one hundred times further from the lens than the object is, there will be a greatly magnified representation of the object. It will only be seen, however, under ordinary illumination; and it is therefore necessary to have a very strong light, concentrated by a suitable mirror or glass, and directed upon the object. When artificial light is employed, as of a lamp, the instrument then becomes a magic lantern. It consists of an argand burner placed in a dark lantern, on one side of which is a concave mirror, the vertex being opposite to the centre of the flame, which is placed in its focus. The lantern is made of tin japanned; and to



carry off the smoke from the flame, it is provided with a tube T at the top. L is the light, and MN a concave mirror to give strength to the light, and send the rays through the tube AB in front. At A in this tube is a hemispherical illuminating lens, and there is a convex lens at B. In the middle of the tube there is a wide part CD, open at the sides, for the reception of *slides*. These slides are slips of glass on which pictures are painted; and the principle of the apparatus consists in forming a representation of the picture, in a magnified size, on a distant white wall or screen S. The slide being placed in one of the conjugate foci of the lens B, the image is consequently enlarged. By bringing the lantern nearer the screen, we diminish the representation, because we cause the rays to strike the screen at a point where they are less divergent. It is an improvement in exhibiting the representations from the magic lantern, to cause the images to fall on a piece of distended and wetted muslin, behind which the spectators are placed. Lately, the mode of representing scenes has been further improved by using two lanterns, placed at equal distances; in this case, while the view in one is being withdrawn, the view in another is coming on, and the eye is charmed with seeing, for example, a scene in winter dissolve and assume the appearance of a similar scene in summer.

ACOUSTICS.

The term ACOUSTICS is derived from a Greek word which signifies *I hear*, and is applied to that branch of natural philosophy which treats of the nature of *sound*, and the laws which determine its production and propagation.

Atmospheric vibration is allowed to be the cause of sound. For instance, a bell is struck by its clapper—the body of the bell consequently vibrates, as we may

sensibly assure ourselves by applying our nail lightly to the edge: in its agitation, it beats or makes impulses on the air, which, yielding under the stroke or pressure, is compressed or condensed to a certain distance around. The compressed air instantly expands, and in doing so, repeats the pressure on the air next in contact with it; and thus each one of the original strokes of the vibrating metal sends out a series of *shells* of compressed air, somewhat like the waves dispersed over a lake from the dropping of a stone into its placid bosom, and, like them, always lessening in bulk and force. These *shells* are from two inches to thirty feet in thickness. The air, thus agitated, finally reaches the ear, where it gives a similar impulse to a very fine nervous membrane, and the mind then receives the idea or impression which we call a *sound*.

With regard to the velocity with which the impulse of sound advances, it appears, from the most accurate experiments on the discharge of pieces of ordnance, and marking the interval between the flash and the report, at a distance carefully measured, that when the atmosphere is at the temperature indicated by 60° of Fahrenheit's thermometer, sound travels at the rate of 1125 feet per second, which is nearly equal to the velocity of a cannon-ball the moment it issues from the piece. The ball is very speedily retarded by the resistance of the air, but sound advances with undiminished velocity, though unequal intensity. It will travel a mile in little more than four seconds and a half, or twelve and three-fourth miles per minute. On this depends an easy method of determining in many cases our distance from objects, and which may often prove useful, particularly in thunder-storms. We have only to observe in seconds the interval between the flash and the report, and allow four seconds and a half to every mile, or 1125 feet to every second. It is remarkable, also, that all kinds of sounds, strong or weak, acute or grave, advance with the same velocity; and this arises from the circumstance, that all the oscillatory movements in the air, however minute, or however extended, are performed each in the very same interval of time. For every degree of Fahrenheit above 60°, the velocity of sound is increased about $1\frac{1}{4}$ feet, and for every degree below 60°, it is lessened in the same measure; so that when the temperature is at the freezing-point, the rate is only 1090 feet per second.

That air is the vehicle of ordinary sounds is evident from the fact that a bell rung in the exhausted receiver of an air-pump can scarcely be heard. But certain liquids and solids also convey sound, and that with greater velocity and loudness than air. Thus, through water it moves with a velocity of 4708 feet in a second, or more than four times that in air; through tin it is $7\frac{1}{2}$, through copper 12, oak $10\frac{2}{3}$, beech $12\frac{1}{2}$, elm $14\frac{2}{3}$, and through brass and iron $16\frac{2}{3}$ times quicker than in air. A very weak sound—as the scratch of a pin, or the ticking of a watch—made at one end of a log of wood, can be heard by an ear applied at the other end, though it would produce no audible sound at the same distance in air. Savages apply their ear to the ground when they wish to hear any noise that is weak or distant, such as the approach of men or horses. This is the principle of the *stethoscope*. It consists of a wooden cylinder, one end of which is applied to the outside of the patient's chest, the other to the ear of the physician. He is thus enabled to hear the sounds made by the breath in the lungs, and the blood in the heart and blood-vessels, and being familiar with the healthy sounds, can detect any deviations, and thus learns the condition of these viscera.

For transmitting articulate sounds to a distance, *speaking-tubes* are used, by which persons can communicate though in different apartments of a building. The sound is in this case conveyed by the air, and the tube acts by preventing the sound from being diffused and weakened.

In consequence of sound requiring a certain length of time to travel, it is impossible for two sounds, at any distance from each other, to be heard at the same moment by persons who are not at equal distances from both. 'If two persons, A and B,' says an American writer, 'are standing at the distance of one mile from each other, and each fires a gun at the same moment, A will not hear B's gun until several seconds after he hears his own, because the sound will require that time to pass through the distance between them. And the same will be the case with B. One might at first suppose that if A should wait and fire at the moment he hears the report from B, the two sounds would then be heard together. A would hear them together; but the time that must elapse after B had fired, before the sound from A would come to *him*, would be greater than if they fired at the same moment; for he must wait till the sound of his own gun had gone to A, and then until the sound of A's discharge should return to him. It is thus evidently impossible for two persons, standing at a distance from each other, to produce a sound which shall be heard by both at the same time.

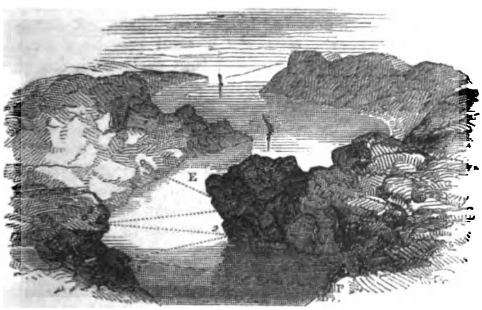
'It is on account of this principle, that in long ranks of soldiers, where two bands of music are placed at a considerable interval from each other, it is impossible for the two bands to keep time with each other. They may indeed play together, but each soldier will hear the nearest sounds quickest, and thus they will seem to be out of time. It is often noticed, too, that if from an eminence we look upon a long column which is marching to a band of music in front, the various ranks do not step exactly together. Those in the rear are in each step a little later than those before them. This produces a sort of undulation in the whole column, which is difficult to describe, but which all who have noticed it will understand. Each rank steps, not when the sound is *made*, but when, in its progress down the column at the rate of 1125 feet per second, it reaches their ears. Those who are near the music hear it as soon as it is produced, while the others must wait till sufficient time shall have elapsed for it to have passed through the air to them.

'Should a commander stand at the distance of a fifth of a mile from his army, and command them to fire, they might all obey at the moment when the word of command reaches them; but the officer will hear the report of the guns from those at the side nearest him first, then those a little further off, and so on to the most remote. Thus, though all might obey with equal alacrity, the sounds will not, and cannot, appear simultaneous, for the reports of the distant guns must be delayed long enough for the command to pass from the officer to the men, and then for the sound to return. All attempts, therefore, to make the firing appear exactly simultaneous from a long line must be in vain.'

An *echo*, or duplication of sound, is one of the most interesting phenomena in acoustics. The cause of it is precisely analogous to the reaction of a wave of water. When a wave of water strikes the precipitous bank of a river, it is thrown back in a diagonal direction to the side whence it came, and there again strikes on the bank. In the same manner, the pulses or waves of sound are reflected or thrown back from flat surfaces which interrupt them, and, thus returning, produce what we call an echo. It is evident that the smoother the surface which reflects the sound, the more perfect will be the reverberation. An irregular surface, by throwing back the wave of sound at irregular intervals, will so confound and distract it, that no distinct or audible echo will be reflected. On the contrary, a regular concave surface will reflect sound in such a manner, that at a certain point the reflections from each part of the concave surface will be concentrated into a focus capable of producing a very powerful effect. The quickness with which an echo returns to the spot where the sound originates, depends of course

upon the distance of the reflecting surface; and since sound travels at the rate of 1125 feet in a second, a rock situated at half that distance will return an echo in exactly one second. The number of syllables pronounced in a second will in such a case be repeated distinctly, while the end of a long sentence would blend with the commencement of the echo.

An echo may be double, triple, or even quadruple, according to the nature and number of the projecting surfaces from and to which the sound is allowed to play. Distinctly marked echoes of this combined order may sometimes be heard in the vaults of cathedrals, in which case the waves of sound are driven from side to side of a deeply groined arch, and reverberate in protracted peals. One of the most interesting echoes of this kind in nature, is that which occurs on the banks of the Rhine at Lurley. If the weather be favourable, the report of a musket, fired on one side, is repeated from crag to crag on opposite sides of the river alternately, as represented in the figure; where P is considered as the



primary point of radiation for the sound, which crossing the river, strikes at 1, then is sent off to 2, and so on to 3 and subsequent points, stopping, or faintly dying away, opposite E.

There are some remarkable echoes in ecclesiastical structures, arising from peculiarities in the construction. In erecting the baptistry of the church of Pisa, the architect, Giovanni Pisano, disposed the concavity of the cupola in such a manner, that any noise from below is followed with a very loud and long double echo. Two persons whispering, and standing opposite to each other, with their faces near the wall, can converse together without being overheard by the company between. This arises from the elliptical form of the cupola, each person being placed in the focus of the ellipse. In the cathedral church of Gloucester, there is a whispering-gallery above the eastern extremity of the choir, which extends from one end of the church to the other. If two persons, placed at considerably distant points, speak to one another in the lowest voice, it is distinctly heard. A similar effect is produced in the vestibule of the Observatory of Paris, and in the cupola of St Paul's in London. A tourist has mentioned that in Italy, on the way to Naples, and two days' journey from Rome, he saw in an inn a square vault, where a whisper could easily be heard at the opposite corner, but not at all on the side-corner that was near to you. This property was common to each corner of the room. He saw another on the way from Paris to Lyon, in the porch of an inn which had a round vault. When any one held his mouth to the side of the wall, his whisper could be heard on the opposite side.

The whispering-gallery in St Paul's, London, is a great curiosity. It is 140 yards in circumference, and is just below the dome, which is 430 feet in circumference. A stone seat runs round the gallery along the front of the wall. On the side directly opposite the door by which visitors enter, several yards of the seat are covered with matting, on which the visitor being seated, the man who shews the gallery whispers with the mouth near the wall, at the distance of 140 feet from the visitor, who hears his words in a loud voice, seemingly at his ear. The mere shutting of the door produces a sound like a peal of thunder rolling among the mountains. The effect is not so perfect if the visitor sits down half-way between the door and matted seat, and much less if he stands near the man who speaks, but on the other side of the door.

It is of great importance that buildings designed for large auditories should be constructed in such a manner that the voice of the speaker will neither echo from the walls nor be lost to the hearers. The best known form of apartment for the proper distribution of sound, is that in which the length is from a third to a half more than the breadth, the height somewhat greater than the breadth, and having a roof bevelled off all round the sides. This species of ceiling, called technically a coved or *coach roof*, from its being lower at the sides than centre, is in all cases best suited for conveying sounds clearly to the ears of auditors.

MUSICAL SOUNDS.

There is a peculiar character in sounds, depending on the character of the sounding body. A blow with a hammer, or the report of a pistol, produces only a noise. But if a body be of such a thinness and tightness as to produce a succession of impulses of a sufficient degree of quickness, a *tone* is the result—namely, a sound composed of a great number of noises, all so close upon each other, that they bring but one result to the ear. Wires and strings of metal and catgut, slips of metal, fine membranes, and columns of the air itself enclosed in tubes, are the most familiar means of producing sounds of this kind. Such sounds are said to be musical.

The study of musical sounds, as a branch of natural philosophy, is calculated, perhaps, to give as much pleasure to the man of science as music itself can convey to those who are gifted with what are called good ears. The natural character of these sounds, and their relations to each other, are very remarkable; while the relation of the whole to the human mind must be regarded as one of the most interesting proofs of creative design which the entire circle of nature presents.

The principal sounds of music may be said to be only seven in number. There are other five, which may be produced by the voice with some little difficulty; but the voice, in an untutored condition, gives forth only seven. The notes are of different degrees of shrillness, one rising above another in succession. A person who knows nothing of music beyond having heard another sing or play, and having seen the key-board of a pianoforte, will be ready to say that there are more notes than seven; but there are only seven that are, strictly speaking, various. The voice, or an instrument, may run up into other notes; but all of these are repetitions of the first seven, and identical respectively with them, in all respects except shrillness. In ordinary pianofortes, there are at least six repetitions of the seven notes, so that the uppermost keys are shriller than the voice of a child, while the lowest rumble like a drum.

The seven notes are named *Do*, *Re*, *Mi*, *Fa*, *Sol*, *La*, *Si*, or by the first seven letters of the alphabet in a peculiar arrangement—namely, C, D, E, F, G, A, B. They

are here represented in the well-known language which musicians present to the eye (using the *treble clef*).

Let an ordinary piece of catgut or violin string be extended between two points on a board, and screwed up. It may be made, according to its length and degree of tension, to vibrate, when struck, exactly 240 times in

a second. The note which it thus produces is C, or Do; and a man, on trial, will find that this is the note with which he is most apt to begin a song, when he attempts to sing. The note in his voice will be perfectly in unison with the note produced by the string; that is to say, they will melt into and agree with each other, and the effect will be pleasant. This is because the membrane at the top of the singer's windpipe (the instrument of his voice) vibrates exactly the same number of times in a second, producing that note, as the string does. The equality in the number of vibrations is what makes the notes the same, and the effect harmonious and agreeable.

We shall suppose the string to be forty-five inches long that produces the note C of 240 vibrations in a second. Being extended between two pegs near the surface of a board, the experimenter may place his finger upon it right in the centre, and twang or strike either half, when he will find a much shriller note produced, being, in reality, the first C, or Do, of a new series of the seven notes. In this case, the vibrations are exactly double—namely, 480 in a second—these being always the more rapid the shorter the string or the greater its tightness. The second or upper C is called the *octave* of the first, being the eighth note above it.

We shall now suppose that the string is shortened only so far as to leave thirty inches, or two-thirds of its length, free for twanging. This shorter string will sound the note G, or Sol. In this case, as the length of string is two-thirds, so are the vibrations three-halves, or one and a half times those in the former instance; namely, 360. All the other notes are produced by different proportions of string and numbers of vibrations, as shewn in the adjoining scale.

- C or Do (octave), 22½ in. 480 vib.
- B or Si, 24 in. 450 vibrations.
- A or La, 27 in. 400 vibrations.
- G or Sol, 30 in. 360 vibrations.
- F or Fa, 33¾ in. 320 vibrations.
- E or Mi, 36 in. 300 vibrations.
- D or Re, 40 in. 270 vibrations.
- C or Do, 45 in. 240 vibrations.

What is remarkable here is the curious mathematical proportions on which the various notes depend. Taking the first C as one, and its octave as one-half, we have various lengths of string for the intermediate notes, in the following proportions:—namely, for D, eight-ninths; for E, four-fifths; for F, three-fourths; for G, two-thirds; for A, three-fifths; and for B, eight-fifteenths; all of which proportions are exactly reversed with regard to the numbers of vibrations, these being in succession nine-eighths, four-fifths, &c. The proportions, as clearly appears to the eye from the above scale, are not regular: the string is first shortened five inches, then four, then two and a quarter, next three and three-quarters, and so on. Nevertheless, these are the musical notes which the voice naturally gives forth, and which the mind recognises as beautiful. The string twanged at lengths which would appear in more regular proportion, would give forth musical sounds, but not the seven notes of music—not those peculiar sounds which all nations recognise as such, and which nature has manifestly appointed to serve in that character.

Irregular as the proportions appear, there are some of the seven notes which are more proportioned to each other than the rest. They are said to be more in *harmony* with each other; and the effect when they are struck together is pleasing. It is to be observed, in the first place, that a note always harmonises well with its *octave*, or the eighth or repeating note above it. This is supposed to be because the vibrations of the one note in that case are exactly two for one of the other. The first Do also harmonises well with Sol (G), which is called its *fifth*, being the fifth note above it; and this is, on the same supposition, because the vibrations are in that case as three to two, which is also a symmetrical proportion. Harmony is also produced when some other notes are sounded at the same moment with those which are third above them (their *thirds*); and this may be accounted for in a similar way. Thirds, fifths, and octaves are, therefore, pleasing or harmonious sounds; while seconds, fourths, sixths, and sevenths are less so.

Experiments of a very curious nature have been made on this subject. It may readily be observed by the naked eye, that when one of the longer strings of the harp or pianoforte is struck, there is not only a vibration along the whole length, giving it an elliptical appearance, but there are also vibrations of shorter lengths of the same string going on at the same time. It has been found, when light pieces of paper are hung across the string, that they settle at certain places, shewing that the principal subordinate vibrations correspond with octaves, fifths, and thirds. A drum, or a sonorous board, over which sand has been strewn, will, if beat, throw the sand into curious figures of a determinate and regularly recurring character. There are even more curious facts connected with the harmonious notes. The *cries* of a city—that is, the scarcely articulate, but often very musical, sounds uttered by persons selling things on the streets—generally rise on thirds or fifths, sometimes on octaves; and this although few of these poor people have ever been taught music. The cry of oysters by women in Edinburgh is, for example, always on an octave.

With respect to the sounds produced by wind-instruments, the effect is caused by the vibrations of a column of air confined at one end, and either open or shut at the other. The length of the sounding column determines the nature of the vibrations; but along with the fundamental tone, there are interior and subordinate vibrations. The whole column divides itself into regular portions—equal to the half, the third, and so on, of the longitudinal extent—in the same manner as we shewed was the case in stringed instruments. We may observe something similar to these vibrations in the contraction and expansion of a long and very elastic string, to one extremity of which a ball is attached. A spiral spring also shews, and perhaps more clearly, the repeated stretching and recoil. If suddenly struck at one end, it will exhibit not only a vibration throughout its whole extent, but likewise partial ones, which wind vermicularly along the chain of elastic rings. If the air be struck with great force, the subordinate vibrations sometimes predominate, and yield the clearest and loudest tones. This may be observed in the dying sounds of a bell, which rise one or two octaves, and expire in the acutest note. Upon the degree of force with which the instrument is blown, depends the performance of the bugle-horn, whose compass is very small, consisting only of the simplest notes. In other wind-instruments, the nature of several notes produced depends upon the length and size of the tube, or the positions of the holes in its sides. In the organ, there is a pipe for each note, and wind is admitted from the bellows to the pipes by the action of keys similar to those of a pianoforte. The organ may be played also by a barrel made to turn slowly under the keys, and to lift them in passing, by means of pins projecting at certain determinate intervals from the surface of the barrel. In wind-instruments which are furnished with reeds, the tone depends on the stiffness, weight, length, &c., of the vibrating plate or tongue of the reed, as well as on the dimensions of the tube or space with which it is connected.

For further information on the theory and practice of music, see MUSIC (*Chambers's Educational Course*).

ELECTRICITY—MAGNETISM—ELECTRO-MAGNETISM.

ELECTRICITY.

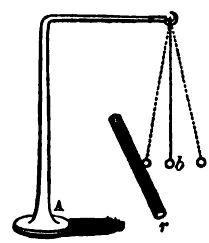
IT was observed in ancient times, that when amber was rubbed, it acquired a power of attracting and repelling such light bodies as hair and feathers; and this power afterwards came to be called ELECTRICITY, from *electron*, the Greek word for amber. Although the ancients were thus familiar with some of the more obvious phenomena of electricity, they did not investigate the subject methodically, or attempt any generalisation of facts into a scientific theory. It was only in modern times, when close reasoning from truths, established by the evidence of the senses, began to be practised by philosophers, that the phenomena connected with electricity assumed the dignity of a science. Dr Gilbert, an English physician, made the first step towards generalisation in the year 1600. He published a valuable treatise, in which he observed that not only amber, but various other substances, can, by friction, be made to draw light bodies to them. Boyle, Guericke, Newton, and some other philosophers of that period, contributed to extend human knowledge upon this interesting subject; but the real science of electricity took its rise in a later age. About the middle of the eighteenth century, several very remarkable facts were ascertained, particularly by Benjamin Franklin, which identified lightning with electricity; but the extensive relations which connect it with so many other departments of physical science were not discovered until the present century, nor was their importance until then appreciated. In this short era, a new science has arisen, founded on that modification of electricity which is known by the name of VOLTAIC ELECTRICITY. The voltaic battery (which will be afterwards described), as an instrument for analysing or decomposing chemical substances, has connected it with chemistry in the most intimate manner. Hence has sprung ELECTRO-CHEMISTRY, one of the connecting branches between remote divisions of the philosophy of nature. ELECTRO-MAGNETISM is a still more recently discovered province of science, and which identifies as one two powers which were previously regarded as distinct.

The general facts relating to this subject may be classed under two heads—1*st*, The *Excitation* of Electricity; and 2*d*, The *Distribution* of Electricity. Connected with each of these heads are various phenomena, which we shall notice as they occur during the gradual development of the subject.

EXCITATION OF ELECTRICITY.

If a stick of sealing-wax, a bit of amber, the glass of a watch, or any other smooth piece of glass, be rubbed upon dry flannel or woollen cloth, or even the sleeve of a cloth coat, it will be found to have acquired a new and very singular physical property. This property is exhibited by holding the body which has been subjected to friction over small and light substances, such as shreds of paper, goldleaf, feathers, straw, cork, &c. These will be first instantly *attracted* to it, some of them adhering to its surface, others falling back to the place whence they were withdrawn, whilst others are thrown off from the body, as if they were *repelled* from it. Here, then, is a distinct phenomenon—a process of attraction and repulsion at the same instant, which requires careful examination.

The phenomena of attraction and repulsion may be exemplified in a striking manner by a small apparatus, of which we adjoin a representation. A is a stand bent at its upper extremity, and having a hook to which a fine silk thread is attached, with a very small pith-ball at its end *b*. Rub a dry rod of glass *r*, and, on presenting it to the ball *b*, the ball will be immediately attracted to the glass, and will remain in contact with it. After they remain in contact for a few seconds, if the glass be withdrawn without being touched by the fingers, and again presented to the ball, the latter will be *repelled*, instead of being attracted, as in the first instance. By being touched with the finger, the ball can be deprived of its electricity; and if, after this has been done, we present a piece of sealing-wax in place of the glass formerly employed, the very same phenomena will take place: on the first application, the ball will be attracted; and on the second, repelled. It is clear, then, in the first place, that both these electrics—the glass and the wax—have the power of attracting another body before they have communicated to it any of their own electricity; and, secondly, that they repel the body after they have communicated to it a portion of their own electricity.



But a very remarkable circumstance takes place, if we, after having conveyed electricity to the ball *b*, by means of excited glass, which has been for a moment or two in contact with it, should present to it, after the former was withdrawn, excited sealing-wax: the ball, instead of being *repelled*, as it would be were the glass again applied, is *attracted* by the wax. If the experiment be reversed, and the excited wax first presented to the ball, and then the excited glass, the latter will be found to attract the ball. 'Hence it follows,' says Sir David Brewster, 'that excited glass *repels* a ball electrified by excited glass. Excited wax *repels* a ball electrified by excited wax. Excited glass *attracts* a ball electrified by excited wax. Excited wax *attracts* a ball electrified by excited glass. From which we conclude that there are two opposite electricities—namely, that produced by excited glass, to which the name of *vitreous* or *positive* electricity has been given; and that produced by excited wax, to which the name of *resinous* or *negative* electricity has been given.

'If, when the pith-ball *b* is electrified, either with excited glass or wax, we touch it with a rod of glass, its property of being subsequently attracted or repelled by the excited glass or wax will suffer no change; but if we touch it with a rod of metal, it will lose the electricity which it had received, and will be attracted either by the excited glass or wax, as it was when they were first applied to it. Hence the rod of glass and the rod of metal possess different properties—the former being incapable, and the latter capable, of carrying off the electricity of the pith-ball.'

In these experiments, electricity has been produced by *friction*; but there are other methods of obtaining it, which, however, will be afterwards explained.

With regard to attraction and repulsion, a few facts remain to be stated. Some substances remain longer in contact with the electric than others, and two bodies which have both been in contact with the same electric mutually repel each other. If electrics of considerable size are employed, the phenomena of course are better observed; and if the experiment be performed in a

darkened chamber, flashes of bluish light will be seen to extend over the surface of the electric submitted to friction, which we shall suppose is a cylinder of sealing-wax, sulphur, or glass. Sparks, accompanied also with a sharp snapping sound, will be seen to dart round it in various directions. If a round body, as a metallic ball, be presented to it, and moved from one end to the other, a succession of sparks will be obtained as the ball passes along the surface; and if the knuckle be presented, instead of the metallic ball, each spark will be accompanied by a pricking sensation. If a metallic globe be suspended in the air by silk threads, and in that situation rubbed by an electric, it will also become electrical, and exhibit the same properties as an electric. It is essential to the success of this experiment that it be *insulated;* that is, cut off, by means of a non-conductor, from all communication with any substance, except the air and the electric which sustains it.

DISTRIBUTION AND TRANSFERENCE.

We have noticed that when the excited electric was brought near the pith-ball *b*, the latter was first attracted, and then repelled. If we now remove the electric, and present to the ball which has thus touched it, a second ball which has had no previous communication with an electric, we find that these two balls attract one another, and come into contact. The same actions are repeated between this second ball and a third which may be presented to it; and so on in succession, but with a continued diminution of intensity. This diminution plainly indicates a diminished power, in consequence, as it would seem, of its being distributed amongst a number of bodies. It is clear, therefore, that the unknown power which we have called electricity can, like heat, be transferred or communicated from one body to another, and that its intensity, like that of heat, is weakened by being diffused amongst a number of bodies. An electrified ball can be deprived of its electricity by being touched with a rod of metal of any kind; but if we touch it with glass or wax, it will not be carried off. Hence, metals are said to be *conductors*, and glass and wax *non-conductors*, of electricity. Non-conductors obstruct the passage of electricity, and are therefore called *insulators*, because they coop up the electricity where it is, as in an *insula* or island.—It is to be observed that electricity is not conducted through the substance of bodies, like heat, but is confined entirely to the surface.

There is no absolute distinction between conductors and non-conductors; they differ only in degree. The excitement runs along the surface of a metal with inconceivable rapidity, but even metals have been proved to offer some obstruction, and to retard its passage in an appreciable degree. Wax and glass, again, do not entirely prevent the passage of electrical excitement. All bodies, then, are conductors in a greater or less degree, and the worst conductors are the best insulators.

In the following list, the bodies are arranged in the order of their conducting power, beginning with the best and ending with the worst:—

All the metals, charcoal, strong acids, saline solutions, water, living vegetables and animals, damp air, flame and smoke, alcohol, moist earth and stones, oils, ashes, lime, porcelain, dry vegetable bodies, dry gases and air, feathers, hair, silk, gems, glass, wax, sulphur, resins, amber, shell-lac, gutta-percha.

This list becomes one of insulators if read backwards, the best insulators standing last—gutta-percha, shell-lac, &c. In the middle of the list, conductors and non-conductors merge insensibly into one another. The conducting power of water, though not the highest, is still great, and hence the very best insulators become conductors when wet or damp. Water becomes a very imperfect conductor when in the state of ice below 13°, or in that of dry steam. Glass, from its solidity and strength, is much used as an insulator, though it is inferior to the resins, especially shell-lac. Insulators made of other substances are often coated with lac, which prevents the deposition of moisture. A cotton or linen thread may be reckoned a conductor, though imperfect; silk is used as a non-conductor. Air, it is clear, must be a good insulator, otherwise the electricity, when excited, would speedily disappear from the surface of bodies, which is not the case if the air be dry. Temperature affects the conducting power of bodies; glass heated red becomes a conductor, and so do resins when melted. The metals, again, conduct less perfectly when heated.

It was formerly considered that the insulators were the only bodies that electricity could be excited on; hence they were also called *electrics*, while the conductors—such as the metals—were called *non-electrics*. But this supposition is false. The metals are excitable by friction the same as the resins; but, from their being good conductors, the electricity is apt to disappear from their surface as fast as it is formed. It is possible, by proper insulation, to make them electric, as well as sealing-wax or glass. In the electrical machine, the electricity is produced by the rubbing of a metallic surface on glass. The distinction of electrics and non-electrics, therefore, is no longer admitted.

The earth is considered the general reservoir of electricity: whenever any excitement is connected with the ground by a good conductor, it passes thither, and is lost by dissipation, like a wave spreading out on a boundless sea. The earth is generally neutral, or very slightly charged: and electricity of high tension will always run towards a body with either no charge, or with a feebler charge, and still more with an opposite charge.

When an electrified surface, or an electric charge of any kind, has two connections with the ground, or with neutral surfaces where it can spread, it always passes by the best conductor, even although this should be by far the longest path. Thus, a metallic rod would be preferred to a line of water, water to dry wood, and wood to glass.

THE TWO KINDS OF ELECTRICITY.

It will be understood, from the preceding explanations, that there are two kinds of electricity—namely, a *vitreous* or *positive* electricity, and a *resinous* or *negative* electricity. Although we have thus two electricities, there does not appear to be the smallest difference between them when they are taken individually. The distinction is only observable when brought in contact; they then display so marked a contrariety, or mutually opposive force, that they may be viewed as agents having opposite qualities, which completely neutralise one another by combination, just like an acid and an alkali. It is remarkable that the excitation of one species of electricity is always accompanied by the presence of the other, and both are produced to an equal extent. Thus, when a piece of glass is rubbed by silk, just as much resinous electricity is produced in the silk as there is vitreous electricity produced in the glass; and whatever electrified bodies are repelled by the one, are attracted by the other. Of course these two surfaces, having acquired opposite electricities, invariably attract each other. A white and a black ribbon rubbed against each other between the finger and thumb, exhibit electrical phenomena in a very marked manner. The black is resinously, and the white vitreously electrified: of course they attract each other; and if separated, the one attracts the light bodies which the other repels. When two pieces of the same ribbon of the same length are rubbed, the one being drawn lengthways, and at right angles, over a part of the other, the one which has been subjected to friction in its whole length acquires vitreous, and the other resinous electricity.

In performing these and other experiments, an instrument is used called the *electroscope.* A gold-leaf electroscope is represented in the annexed figure. It consists of a glass vessel, into which is inserted a metallic rod, terminating in two gold leaves, and surmounted by a metallic plate. If the plate is touched by a body, however slightly electrified, the excitement passes down to the leaves, and causes them to repel each other, or *diverge.* An instrument with means of measuring the amount of divergence is an *electrometer.* If the leaves of the electroscope are made divergent, say with negative electricity from sealing-wax, when another excited body approaches, it will be at once apparent which kind of electricity it has got: if negative, the leaves will continue to diverge; if positive, they will collapse.

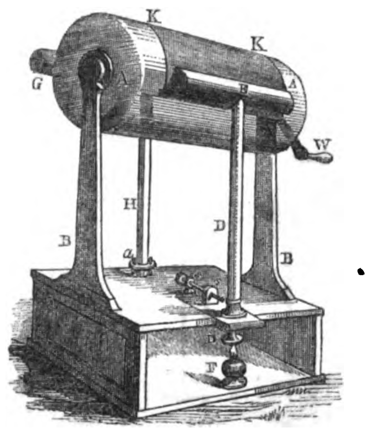
No general law has yet been discovered enabling us to say before trial which of two substances rubbed together will be positive, and which negative. The fur of a cat is rendered positive by friction with every substance that has yet been tried; and smooth glass is also rendered positive by every substance, except cat's fur. Sulphur, on the other hand, has a similar tendency to become negative, whatever it be rubbed with. In general, it is observed that hardness in a body predisposes it to receive positive electricity, as does also smoothness. If two pieces of the same material are rubbed together, the one being rough, and the other smooth, the rough one will be negative, and the other positive. The one in general that takes most heat from the friction is negative. But experiments with the same substances sometimes give opposite results.

In rubbing metals to produce electricity, it is necessary to rub with large sweeps, to prevent the two electricities from joining together at the instant. The conducting power of the metals is such, that the excitements produced on the touching surfaces are very apt to run together, and neutralise each other on the spot.

Electrical phenomena are generally accounted for by supposing that there is an extremely subtile and highly elastic fluid which pervades all material substances, but is itself devoid of any sensible gravity. It is supposed to move with various degrees of facility through the pores or actual substance of various kinds of matter. Hence, in proportion as they admit of the fluid passing through them with ease or difficulty, bodies have been divided into conductors and non-conductors. According to the doctrine of there being but one species of fluid, it is supposed that the electrical equilibrium which constitutes the natural state of matter, is disturbed by friction, and that one of the two bodies brought near to each other attracts to itself a surcharge of the fluid, and is *over-saturated,* whilst the other is left in a deficient state, and is *under-saturated.* For this view of the subject we are indebted to Franklin; and hence the terms of positive or plus, and negative or minus, have arisen. But as some of the appearances cannot easily be reconciled to the hypothesis of a mere excess or deficiency of one fluid, there is another theory which supposes the fluid to be a *compound,* susceptible of decomposition by friction and other means; hence the origin of the terms vitreous and resinous electricities. With respect to the intensity of the electric force, it resembles that of gravitation, by being inversely as the square of the distance. Like gravitation, also, it acts at all distances, and it is not impeded by any intervening body, provided it be not in an active electrical state. But whilst the particles of each fluid repel those of the same kind, they exert, as we have seen, a high attractive power over those of an opposite kind. The intensity of this attraction also, like that of gravitation, increases with a diminution of distance. It is evident, therefore, that from the powerful attraction which they have for each other, they would always flow towards each other, and coalesce, were it not that the non-conducting properties of electrics offer an impediment to their motion.

ELECTRICAL MACHINE.

In order to procure electricity in large quantities, and of great intensity, a rubbing-machine is constructed, called the Electrical Machine. Its essential parts are *a cylinder of glass,* mounted on an axle on which it may be turned, a *cushion* covered with a metallic paste, and a *metallic cylinder* to take the electricity off from the glass. The figure represents such a machine. AA is the glass cylinder, revolving on an axis in the two supports B and B, which are either of wood or glass. E is a cylinder,



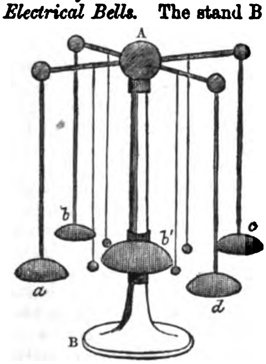
carrying the cushion that rubs on the glass. This cushion is commonly separable from the cylinder, and when placed in it, rests on a spring, which keeps it close to the glass during the friction. The cylinder E has a metallic surface of brass or tin, and it is supported on a pillar D, which is an insulator made of glass. On the other side of the glass cylinder is the metallic cylinder G, destined to receive the electricity evolved on the former. It does not of itself rub on the glass, but it is armed with a row of brass points, which almost touch the excited cylinder, and which are specially adapted to carry off the electricity, and spread it over the metallic surface. This cylinder is called the Prime Conductor, or first receiver of the excitement, and it is supported by a glass pillar H, in order to be insulated. As the electricity of glass is positive, this cylinder must always receive positive electricity; hence it is called the Positive Prime Conductor. Since the cushion cylinder gets itself charged with negative electricity, it is called the Negative Prime Conductor. The base of the pillar supporting the negative conductor is movable by a screw *aa*, to regulate the pressure of the cushion. A flap of silk, KK, is fastened to the upper edge of the cushion, and covers the upper half of the cylinder; this may both increase the friction given to the glass, and help to retain the electricity on the surface till it go round to the points on the prime receiver. The surface of the cylinder and of the insulating pillars must be kept warm and dry during the working of the machine; and for this purpose a permanent heating body is sometimes kept near, such as an iron heater or a lamp, F, applied to the hollow, D, of each glass pillar. Although the cushion cylinder is on an insulating stand, it is not generally insulated when the machine is worked; insulation is used merely for certain special experiments. Accordingly, it is usual to connect the negative cylinder with the ground by a chain. If it were not so connected, it would become highly

charged with negative electricity, and resist the further disengagement of the excitement.

The metallic paste smeared upon the cushion—a hair-cushion covered with chamois leather—is an *amalgam*, or mixture of six parts of mercury, two of zinc, and one of tin. It is spread on the cushion with a knife, and requires to be renewed from time to time.

The operation, then, consists in turning the cylinder rapidly by the handle W. Its surface is rubbed hard on the metallic paste, which the cushion is smeared with, and electricity is evolved of both kinds. The positive excitement appears on the glass, and is carried round and taken off by the points of the prime conductor, and there accumulated, being cut off from all conducting communication with the ground. The negative excitement is given to the metallic coating of the cushion, and thence to the whole of the negative cylinder; but for the sake of getting additional excitement from the machine to the other side, this is carried to the earth by the chain.

A great number of striking and beautiful experiments can be made by electrifying bodies, and making them display the attractions and repulsions caused by the electricity. One of the most interesting is that with the *Electrical Bells.* The stand B carries upon it at a little height a bell b', and above the bell a glass insulating rod terminating in the brass knob A. From A proceed four brass rods, and from their extremities are suspended by brass rods or chains four bells, a, b, c, d, hanging on a level with the bell b' on the pillar. Four brass balls are suspended by silk threads from the arms running out from A, so as to hang between the outer bells and the central one. Electricity is then conveyed from the prime conductor of the machine to the central knob, or to any of the arms, and runs over the whole of the arms and the outer bells; but it is prevented by the glass pillar from passing to the middle bell, and by the silk threads from passing to the brass balls. The outer bells are therefore highly charged with the electricity of the positive prime conductor, and each attracts the ball next it. The balls move up, therefore, and strike the bells; but no sooner touch them, than they are repelled, and fly in the direction of the central ball; which, being neutral and uninsulated, takes off their electricity, and with it their repulsion from the outer bells; so that the instant they strike upon the neutral centre, they are again attracted to the electrified bells, and immediately repelled as before. Thus, by incessantly swinging between the two, they keep up a tinkling as long as the electricity continues.



Another set of experiments on the same principle is made by feathers, heads of hair, or like bodies. When these are electrified, the repulsion that bodies in the same state always manifest, causes the hair to bristle up, and spread itself out as far apart as possible.

Another form of the electrical machine, more powerful than the one just described, is what is called the Plate Machine—that is, instead of a cylinder, a flat circular plate is used. The cushion must then be double, so as to hold the edge as between one's finger and thumb; and the other parts must correspond to the shape of the glass. Two rubbers and two sets of points are commonly applied to the plate's edge, dividing it, as it were, into four quarters. The objection to such machines is their liability to crack, by the heating that all machines must undergo to make them thoroughly dry before being wrought.

A machine of great power has been constructed, which receives the name of Armstrong's Hydro-electric Machine. It was observed by Mr Armstrong, that a jet of steam rushing out from an iron boiler, made the boiler give off electric sparks, shewing that it had been electrified by this action. Accordingly, iron cylinders have been formed like the boilers of steam-boats, and mounted with tubes for the escape of the steam in the form of jets. The steam is raised to a pressure of two or three atmospheres before the tubes are opened. It is then allowed to rush out in a row of jets, and in doing so it communicates *negative* electricity in great quantity, and of a very intense kind, to the whole outer surface of the boiler, while it is itself positively electrified in an equal degree. The boiler being supported on glass pillars, in order to be insulated, becomes so intensely charged that, if not relieved, it darts off sparks to great distances. No rubbing-machine can equal such an apparatus in power.

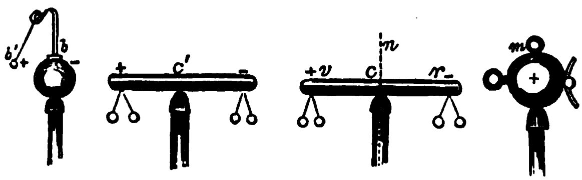
The mode of action in this machine has been thoroughly investigated and explained by Faraday. He has shewn that the electricity arises from the friction of water-globules against the edge of the steam-holes. When the steam rushes out at high-pressure, it carries a shower of water-particles with it, and these act as a rubber upon the metallic surface of the boiler; and the strong friction between water and iron is the source of the electricity. If the steam is dry—that is, if it is perfect steam, or the true elastic gas of water, and free from cloudy or watery particles—it produces no excitement whatever. If atmospheric air, or any other dry gas be used, there is no electricity excited; and it is completely proved that a gas can in no case serve as a rubber to evolve electricity. But if the gas carry with it a shower of particles either *solid* or *liquid*, the surface that it rushes through becomes electrified, and the solid or liquid particles acquire the opposite excitement. It depends upon the substance used what is the kind of electricity given to the metal. The iron boiler is made negative by the water-particles in the steam-current; but if we substitute for water oil of turpentine, olive-oil, resin, or other similar bodies, the solid rubbed by them is positive, and the jet negative. Either steam or dry air may be used to carry the powder, the gas having no action but to sustain the rubbing stream. The action ceases if the water-drops contain any trace of acid or salt, which would render them much better conductors of electricity than drops of pure water. It is from its being too good a conductor, that a metal cannot be electrified by ordinary rubbing, like a piece of amber or wax. But the rapid rush of watery particles succeeds in charging even a metallic surface. If, however, the water is rendered too good a conductor, by an acid or a salt being dissolved in it, the difficulty of keeping the electricities apart is rendered so much greater.

INDUCTION.

It has been seen that when electricity is evolved, both kinds are formed at the same time. The one of the two rubbed bodies has a positive charge, the other an equally strong negative charge. The same principle extends further: we find that a charge cannot even exist on a surface unless there be on some adjoining surface an equal and opposite charge. Positive electricity cannot be insulated, and made to remain by itself; it will not pass into any situation where it cannot be accompanied with a counter-charge of negative excitement. The polar character is rigorously sustained in frictional electricity, as well as in magnetism; we can no more have one kind of excitement alone by itself, than we can have a magnet all north or all south.

When a surface charged with electricity of one kind is in the neighbourhood of other surfaces, but not touching them, it communicates to them the *opposite* electricity. The apparatus best adapted for demonstrating this is a set of brass cylinders rounded at the ends, and placed on insulating stands. Thus, let m be the prime-conductor of a machine; c and c' two insulated

cylinders laid end to end at a little distance from each other and from the conductor; and *b* a brass ball, with a pith-ball *b′* suspended to it. When the machine is wrought, the whole of the surface of *m* has positive



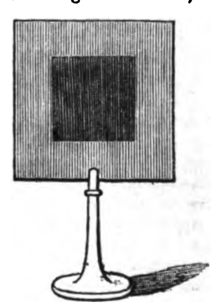
electricity. Now the action of *m* upon the adjoining cylinder is such, that the nearest end *r* is electrified negatively, and the remote end *v* electrified positively. The cylinder has received no electricity by conduction; it has become polarised by induction, exactly as happens in magnetism. The middle, *n*, is neutral, and the two ends are charged with equal and opposite excitements. But this cylinder exerts its action on the second cylinder in the same way; the end of which next *v* is negatively charged, and the other end positively charged. The ball *b* also is affected by the positive end of the second cylinder, and made negative at one side, and positive at the other, where it repels the pith-ball. Thus the prime conductor, without parting with any of its excitement by *conduction*, polarises a series of bodies by its *inductive* power. There is no limit to the number of bodies that might thus act on each other, except the tension of the conductor; but the action on each successive surface becomes gradually feebler.

If the remote end of one of the cylinders is connected by a conductor with the earth, the charge on that end passes off to the earth, and the opposite electricity spreads over the whole surface of the cylinder. Thus, if the positive excitement of *v*, the far end of the first cylinder, were conducted away, the cylinder would possess all over a negative charge, as if it had been connected with the negative prime conductor of the machine. But if, on the other hand, without conducting off any portion of the induced electricity from any of the surfaces, we withdraw the prime conductor *m*, whose tension caused the succession of polarities, they all instantly return to their original neutral condition. The presence of the primitive source is necessary to sustain the action; and when this fails or is cut off, it is like the removal of a magnet from a soft iron bar—the temporary excitement ceases.

We may now understand why an electrified surface attracts a neutral or unelectrified body, such as a pith-ball. It is not that electricity causes attractions between excited and unexcited bodies, the same as between bodies oppositely excited; but that the pith-ball is first rendered opposite by induction, and attracted in consequence of this opposition. A pith-ball at a few inches' distance from an electrified surface is charged with electricity by induction; and the kind being contrary to the kind of the surface, attraction ensues; when the two touch, they become of the same kind by conduction. The case of attraction by excited surfaces is the same as the magnet's attraction for iron: an opposite excitement is first communicated to the body, and it is then attracted. If a series of cylinders were electrified as above shewn, they would all tend to attract each other by their opposite poles.

It is a fact only lately discovered, that neither the prime conductor of the machine, nor any surface whatever, can receive or contain electricity, unless there be other surfaces near to contain an opposite charge of the induced kind. Whatever bodies are in the neighbourhood, the walls and furniture of a room, &c., are made use of for this purpose, as well as anything that is casually brought near. If the surrounding surfaces are easily excited, and can take on the induced electricity well, the prime conductor of the machine, or any connected surface, may acquire a high charge; but if these surfaces are difficult to excite, if they are of the non-conducting kind, the prime conductor will receive only a feeble charge. The second pole is in this case not readily observable—it has a sort of irregular character; but decisive experiments were made by Faraday, which proved that where there is not a confronting surface for the induced charge, it is impossible by the most powerful machine to put the least possible excitement on any surface whatever. It had previously been shewn, that if the outer surface of a hollow sphere were charged, no electricity would pass to the inside, although there were a free communication by holes; and Faraday put the thing to the test on a large scale, by constructing an insulated room, which he went into with his electroscopes, while the outside was charged by a large machine; whereupon it was found that no trace of excitement appeared in the inside. The reason is, that there is not room in the interior of a continuous hollow surface for both excitements to exist apart, and yet confront one another.

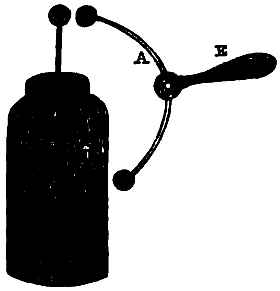
There is a limit placed to the accumulation of electric excitement on any surface. But the better the opposition surface given for the induced electricity, the higher the charge that it is possible to communicate. Accordingly, an apparatus was devised last century by a Dutchman of Leyden, thence called the *Leyden-jar*, which completely suits the polar nature of the charge by providing two equal surfaces, held apart by an insulating medium, to receive both the primary and the induced electricity. The simplest form of this double-surface apparatus is a pane of glass, with a coating of tinfoil on each side, the coatings being equal to one another, and smaller than the glass, so as to leave an uncoated margin all round, as represented in the figure. If one of the coatings is connected with the machine, and positively charged, it will act by induction through the glass upon the other coating, and excite it in the manner already described in the case of the row of brass cylinders. The near or inner surface of the second coating will be made negative, and the other surface positive; and if the coatings are insulated, this state will continue. But if the outer



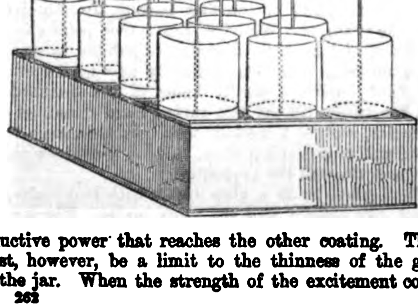
side of the second coating is connected with the ground, and the positive induced charge taken off, the surface will have only a negative charge left corresponding to the positive charge of the first coating, directly derived from the machine. We have thus a true polar charge—a positive and a negative surface separated by an insulating medium. The excitement is now no longer *free*, but *fixed;* and we hardly know of the accumulation that has arisen, till the two surfaces are connected by a conductor, such as a metallic wire; we then see a bright spark, and hear a sharp snap, as if a violent shock had been sent through the apparatus.

The Leyden-jar is a glass bottle with two coatings of tinfoil, one outside, and the other inside. The coatings do not reach to the mouth of the bottle, so that they leave a rim of naked glass. A plug is fitted tightly into the mouth, and covered with varnish, and through the

middle of it a brass rod is passed, with a chain hanging to its lower end, to make a connection with the inner coating. The upper end of the rod is formed into a round knob. The figure represents the jar with the apparatus used for discharging it; which last is a glass rod, E, to hold in the hand, and two brass arms connected at A by a movable joint. Through these two arms the two electricities run to meet one another, when one end touches the outside of the jar, and the other comes near the knob connected with the inside. In using the jar, it may be held in the hand, and the knob presented to the prime conductor of the machine; the inside thus acquires a positive charge, and induces a negative one on the near surface of the *outer coating* fronting it—that is, on the inside surface. The outside surface of the outer coating would then be positive; but it being in the hand, the positive electricity passes away, and leaves the outer coating entirely free for a negative charge, which it thus possesses, and thereby fixes the positive charge in the inside. The transmission of more electricity from the machine to the inner coating, induces more on the outer, till the jar is as highly charged as the strength of the excitement communicated can make it. If, now, we try the outside with a pith-ball or other electrometer, we find no sign of electricity; if we try the inside through the projecting rod, we find, indeed, a very feeble charge; but there is no appearance corresponding to the actual excitement held by the two coatings. Let us next apply the discharging-rod; and having touched the outside with one ball, let us approach the knob with the other; and while these are yet an inch or two inches apart, the two electricities will flash together with the usual spark and noise. The tension or strength of the excitement is shewn by the distance that may thus be broken through by the attraction of the opposite states for one another; just as the strength of the excitement of the prime conductor of the machine is judged of by the distance that sparks will pass through to a conductor placed near.



The strength of charge which can be communicated to a Leyden-jar depends upon the thinness of the intervening glass. The whole *quantity* of the excitement will of course be greater as the jar is larger in size; but its tension, strength, or intensity increases as the thickness of the glass is reduced. The glass offers a certain resistance to the induction, and a certain degree of tension is expended in overcoming this intermediate resistance. The particles of glass are themselves successively polarised, and it is only the surplus of the inductive power that reaches the other coating. There must, however, be a limit to the thinness of the glass of the jar. When the strength of the excitement comes up to a certain point, it forces its way through by making a hole in the glass.



In order to accumulate electricity in great quantity, a series of jars are joined together, forming a *Leyden-battery* (see preceding cut). All the insides are connected by joining their projecting knobs together, and the outsides are connected by passing wires round them from one to another, or resting them all in a continuous metallic bottom. The principle of the charge is the very same as for a single jar; and the effect is nearly what would follow from one enormous jar whose extent of coatings is equal to the sum of those which constitute the battery.

The insulating substance which separates two conducting surfaces, and enables them to sustain opposite states, is called by Faraday a *Dielectric*. All insulators are dielectrics, and the best insulators are the best dielectrics; for in as far as the dielectric is a conductor, it allows electricity to pass through in its own kind to the opposite surface, and thus discharges instead of charging the apparatus. As the glass of the Leyden-jar is not a perfect insulator, but admits a very slow conduction of electricity, the charge necessarily decays, and becomes at last extinct. With sealing-wax or shell-lac the insulation would be more perfect, and the induction better sustained.

The theory of induction furnishes an explanation of the fact that the electricity is generally unequally distributed over the surface of an excited body. In the case of a ball, the excitement is equal on all parts of the surface. But the prime conductor is generally a cylinder rounded at the ends into hemispheres, and the electricity is always stronger on the ends than on the body of the cylinder. If we take a large globe and a small one, and join them together by a rod, and pass electricity upon them, the charge will be most intense in the smallest. Whenever a surface approaches to a point or an edge, the intensity proportionally increases.

The cause is this:—We have seen that without a confronting surface to sustain an opposite charge, no body can possibly receive excitement; and the better provided a body is with a surrounding surface, the greater the charge that it can take on. Now, if we have two unequal balls on the same rod, their excitement depends upon the induction which they can exert on the surfaces about them; but the small ball being in the same room as the large, it has as good and extensive an inductive surface presented to it as the other. The two have unequal surfaces of their own; but they have the same confronting exterior surface in the walls and furniture of the room, and on this unequal proportion of surfaces depends their unequal capacity of being excited. The rounded end of a cylinder is acted on like a small ball; for a larger surface is confronted with it than with an equal portion of the body of the cylinder.

We may now understand the cause of the very great intensity of the excitement at points and edges, and the tendency that the electricity has to pass off from them. A point is a very small surface, confronted with a very large exterior, and the extent of the induced surface allows a very high intensity to be attained. This intensity favours the discharge by increasing the action upon the dielectric of air, so that the electricity will pass off from a point to an opposite body at a much greater distance than it would pass through coming from the round bulge of a large blunt cylinder. Hence, if a surface is armed with points, these will rob it of its excitement, and probably disperse it by their discharging force. The dispersion of the electricity from points is helped in another way. The intense action of points causes a current of charged air to run out from them, whose place is supplied by other air that acquires a charge in its turn, and is repelled like the previous portions. There is always a repulsion created by the passage of electricity from points, which can be made use of to create a rotatory motion, by making a sort of wheel with wire-spokes, ending in points all bent inwards in one direction, and

the whole revolving on an axis. The action is not unlike the force in Barker's mill.

When a Leyden jar or battery is discharged, the electricity may be made to travel through a long circuit, by forming a chain of conducting bodies between the inner and outer coatings of the jar. If a hundred persons, or even more, join hands, and the first touch the outside coating while the last touches the ball communicating with the inside, each will feel the shock at the same instant. The persons in the middle of the series, however, experience a less intense shock than those near the extremities; which seems to shew that the influence flows both ways, thus favouring the theory of two fluids. Electricity in its passage always chooses the best conductors, going out of the direct course to follow them. Its motion through perfect conductors is attended with no perceptible alteration in the mechanical properties of the conducting bodies, provided they be of sufficient size for the charge of the electric fluid transmitted. On the contrary, very considerable effects are produced when a powerful charge is sent through a wire which is too small to allow the whole quantity to pass with perfect freedom, or through an imperfect conductor, though of large size, as is proved when a tree is struck by lightning.

The *disruptive discharge* is the breaking or forcing of the dielectric, as when the glass of the Leyden-jar is broken through. This arises when the twist given to the particles by their electrical state is stronger than their mutual cohesion. Glass is generally able to resist such a power, but the air offers very little resistance; hence disruptive discharges readily occur in it. This discharge may be exemplified by placing a card between one of the balls of the discharging-rod and the coating of a Leyden-jar, and passing the electricity through the card: the opening which it forces can then be seen, and from it we may form some idea of the action that has taken place. The hole is very small, such as would be made by a fine needle; but it is widened on both sides, as if the force had come equally upon it from each coating. Whenever any bad conductor, such as a piece of wood, is put in the way of a discharge, it is split up or pierced in the same manner, if the charge is sufficiently powerful.

The disruptive discharge is always accompanied with a flash of light. This has various shapes, according to the conductors used. Between two good conductors of rounded or blunt surfaces—such as the ball of the discharging-rod, and the side of the jar or its knob—we have the *spark*, which is a round ball or globule of light, which passes somewhat zigzag from one to the other. This corresponds also with the most concentrated and energetic form of the discharge. The distance over which the spark will go disruptively through the air, depends upon the force of the charge, and the goodness of the conducting surfaces between which it runs. From a point, or between a good and a bad conductor, the electricity, passing off, produces a *brush* of light spreading out from a centre. When the air is rarefied, the discharge is made easier, and will pass over a greater distance. In an exhausted receiver, it will pass through two or three feet in a lambent aurora flame. By laying on a glass-plate strips of tinfoil or goldleaf, cut across and separated at every inch or short interval, and passing electricity through the whole, there will be a disruptive discharge, and a spark at every break of the continuity, and the entire metallic line on the plate will be illuminated. A great many striking effects of a similar kind can be produced in the dark from the electric light.

The concussion given to the air by the shock makes the sound that we hear, which is like the sharp crack of a whip. Both the intermediate air and the surfaces discharged are severely agitated by the sudden return from their electrified to their natural state.

There is a very perceptible sulphurous smell accompanying the discharge of electricity. The cause of it has been traced by Professor Schönbein to a peculiar substance formed during the discharge, to which he has given the name of *ozone;* and he has shewn that the same substance is produced in other ways, and has certain remarkable properties, such as the power of bleaching cotton, like chlorine.

When the discharge is interrupted by an imperfect or inadequate conductor, it tears, splits, heats, and sometimes sets fire to bodies. Very thin wires are melted; combustible substances,' such as phosphorus or gunpowder, are inflamed. The human body feels a violent stunning blow when a charge is sent through it; a very strong charge may cause irrecoverable blindness, or even instant death. A Leyden-battery of twelve jars could receive a charge sufficient to kill a man; and accidental deaths have actually occurred in working with such gigantic batteries.

ELECTRICITY OF THE ATMOSPHERE.

Franklin had the glory of discovering the identity of electricity and lightning. By putting up a kite while thunder-clouds were floating in the sky, he actually drew down by the string a distinct charge of electricity.

The electricity of the atmosphere is of the same character as frictional electricity, produced by the machine; but the source of it is a contested point. It was at one time supposed that evaporation evolved electricity, but this is now disputed, and some are of opinion that condensation of vapour has more to do with it. Heat is undoubtedly the cause more or less remotely; for electrical manifestations are more intense the warmer the climate.

The atmosphere is almost always in a state of positive excitement, and the opposite surface of the earth, consequently, negative. The intensity of the excitement undergoes regular daily fluctuations; it has two maxima or highest points, occurring (according to the observations at Kew) at ten A.M. and ten P.M.; and two minima, at two A.M. and four P.M. The intensity is also greater in winter than in summer.

Such may be considered to be the normal condition of the atmosphere. But the deposition of moisture is usually attended with disturbances and irregularities. 'In cloudy weather,' says Dr Noad, 'the free electricity of the air is still *positive.* During storms, or when it rains or snows, it is sometimes *positive*, and sometimes *negative*, and its intensity is always more considerable than in serene weather. During a storm, the electroscope will frequently indicate several changes, from *positive* to *negative.*' The electrical state of the atmosphere is examined by insulated conducting-rods, exploring-wires, and kites.

Thunder.—When a cloud becomes charged with positive or negative electricity, it produces a corresponding excitement, of the contrary kind, as well on the surface of the earth near it, as on the opposing surfaces of adjacent clouds. According to Mr Crosse, the same cloud is sometimes divided into concentric zones alternatively positive and negative. These conditions when sufficiently intense produce a thunder-storm. The clouds are seen to attract one another, and disruptive discharges take place between them. When two clouds are mutually discharged in this way, the whole commotion takes place in the upper air; the lightning is faint and diffused; and the thunder always distant. But when a large mass of positive cloud hangs over the negative earth, and when the intervening air is dry, and the accumulation great, the discharge bursts forth between the sky and the ground, and is then the most terrific and dangerous. The light has the zigzag form known by the name of forked lightning; and it is apt to be concentrated in some one spot, which is scathed and scorched by the stroke. The thunderbolts which throw down or set fire to houses, shiver trees, and destroy life, are of this character. All the effects capable of being produced on the small scale by electrical jars and batteries,

are caused on the grand scale by these thundery discharges between the clouds and the earth.

On the principle that electricity always chooses the best conductor within its reach, Franklin constructed the thunder-rod for protecting buildings. It is a rod of iron or copper, from half an inch to an inch in diameter, rising above the highest pinnacle of the building, and extending down along a wall to terminate in the ground. To receive the excitement more easily, it is pointed at the upper end, or divided into several branches, each ending in a point (see fig.). All pieces of metal on the roof should be connected with the conductor, otherwise these might attract the discharge; and they not being continued to the ground, it must pass from them to the imperfectly conducting stone and wood, and produce its destructive effects. When a house has a metallic roofing, or whether it has or not, strips of lead should be built into the walls, and connected with one another, and with all the metallic masses of the house, so that wherever lightning strikes, it may find a metallic conductor near to convey it harmless to the ground. The rod ought not to terminate in a dry conducting body, but be conveyed, if possible, to moist earth (*e*), or to a well, so that the electricity may be at once discharged into a good conducting medium.

For the protection of ships, a continuous metallic line is necessary from the mast-heads to the sea. But the conductors in this case must be suited to the changes that have to be made in the masts and rigging during the vicissitudes of a voyage; hence they are made into a chain, or formed of thin flexible strips of copper.

If a thunder-storm strike on a house that has no metallic protection, it will choose in preference bell-wires, damp walls, or gilded pictures; a human being will be preferred to dry walls or floors; hence the danger of such a visitation. But the wooden floors are better conductors than woollen cloth or feathers; hence people lying in bed in the middle of a room are likely to escape. The greatest risk is incurred when a good conductor is afforded so far, and then cut short, and an insulating substance succeeds: the lightning is thus attracted and conveyed a certain way with ease, but has then to force its passage by violence, or by going out of its course, to meet in with some tolerable conductor. The human body, from its moist state, stands high in the list of conducting substances, and would be preferred to a great many other things.

SOURCES OF ELECTRICITY.

Hitherto we have regarded friction as the source of electrical excitement; but there are many other ways of evolving it. In general, all disturbances of the molecular state of bodies, whether mechanical or chemical, are liable to produce electricity. Whatever produces heat may also be a source of electricity.

When a plate of mica is cleaved, or a roll of sulphur broken or pounded in the dark, a feeble phosphorescent light is seen. When two unlike surfaces are *pressed* together, and then quickly separated, they are in general found to be in opposite electrical states; but if one of them is a good conductor, the two electricities run together again during the separation. It has been observed that tourmaline, which shews no excitement while its temperature is stationary, becomes electric in the act of heating or of cooling, one of its poles shewing positive electricity, the other negative. The production of electricity by heat constitutes a separate branch of the subject—namely, Thermo-electricity.

VOLTAIC ELECTRICITY, OR GALVANISM.

About the end of last century, an Italian, named Galvani, discovered that by arranging two rods of different metals so that they touched one another at one end, and included between their other ends the leg of a recently killed frog, a convulsive contraction of the limb was produced. It is necessary that one of the metals should touch the nerve, and the other the muscles, in order to produce the effect. The action thus caused by the contact of two metals, or by a triangular circuit formed of two metals and a frog's leg, was found to be the very same as a shock of electricity from the common machine. A new source of electricity, independent altogether of friction, was consequently brought to light. Volta, who followed up the experiments of Galvani, was the first to construct an apparatus for obtaining the excitement in this new principle; hence the kind of electricity so produced is now called *voltaic electricity*, or *galvanism*.

Although the electricity of Volta is undoubtedly the same natural agency as the electricity of the common machine, it has, nevertheless, some characteristics that distinguish it from machine-electricity, besides its peculiar mode of development. It is found to be of feeble *strength* or *intensity*—that is to say, it can never be excited to such a stretch as to inflict the severe blows upon animate or inanimate things that the other can give. The most powerful voltaic machine that has ever been constructed could not strike a man dead, or shatter a resisting obstacle. On the other hand, the voltaic electricity can be produced in much greater *quantity* or amount than we can obtain from friction. The distinction between *intensity* and *quantity*, which is of great importance in reference to the whole of the present subject, may be familiarly illustrated by the case of heat. The *intensity* of heat is its temperature; the *quantity* depends partly on the temperature, but chiefly on the extent of the heated substance. A red-hot poker is of a very high temperature or intensity; but it does not contain so great an amount of warmth as the water of a single hot bath. The electricity of friction may be compared to a red-hot iron, that of Volta to a vast volume of warm water. Now, there are certain purposes that are best served by the high intensity; and others that require merely a great quantity, no matter how feeble the intensity. The chemical and magnetical effects of electricity are dependent on quantity alone; hence these were not produced in a very high degree till after the discoveries of Volta.

The term *current electricity* has also been given to the present branch of the subject, because the excitement arises in a constant stream, and can hardly be said to exist if it is not continually evolved. A Leyden-jar may be charged, and may remain in that state, without requiring a continual supply to be poured into it; hence the common electricity has been called *statical*, or reposing electricity, or electricity in equilibrium. But the other kind must be kept in constant motion, in order to appear at all. The voltaic machine must always be formed into a circle of conductors, where the electricity may flow round and round without interruption; in which case it is produced without ceasing.

It was supposed by Volta that the electricity arose from the simple fact of two different metals touching each other; or that there is a virtue in mere contact similar to the active rubbing of two surfaces. A crown-piece laid on a copper penny would, according to him, evolve electricity; and the one would be positively, and the other negatively charged. But there is no sufficient reason for believing that the simple contact of two bodies, apart from all other influences, is able to disengage electricity.

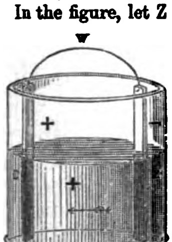
The more common belief as to the source of voltaic

electricity is, that it is due to *chemical combination*, or the union of two substances having a chemical affinity for each other. Such unions commonly produce heat in great abundance; and it can be proved that in most cases of chemical action electricity is always developed. When an acid combines with an alkali, the acid acquires positive, and the alkali negative excitement. So when an acid acts on a metal—as when zinc is plunged into oil of vitriol—the acid is positive, and the metal negative. The action of water in rusting metal would also render the metal negative.

Solutions without chemical action bring forth the electrical excitement. When alkalies are dissolved in water, they become negative, and make the water positive. When acids are mixed with one another, there is no action beyond mere solution; electricity nevertheless arises. If nitric and muriatic acid are mixed at the moment of mixture, excitement may be detected—the nitric acid being the positive ingredient.

The action of the machinery that is used for producing voltaic electricity may now be understood without much difficulty. This machinery generally consists of two metals, and a liquid capable of acting upon metallic bodies by chemical affinity. One of the metals should be acted on as strongly as possible, and the other as weakly as possible. The liquid is commonly an acid, or a corroding salt dissolved in water. Water alone will serve the purpose; but its chemical affinity for metals being faint, compared with acids, it produces feeble effects.

In the figure, let Z represent a plate of zinc immersed in a liquor capable of acting on it, and C a plate of copper; the liquid will combine with the zinc, and give it a negative electricity, and be itself positive; the copper will also be acted on, but more feebly; and hence, instead of being negative, it will receive a positive excitement from the intervening liquid, and act as a conductor to carry round the positive current.



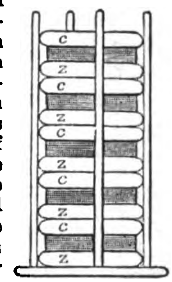
When the plates have no connection outside of the liquid, each is attacked according to the degree that it yields to the agency of the liquid; but when the circle is completed by the wire W joining the unimmersed ends of the plates, the zinc is more attacked than before, and the copper less attacked. The carrying round of the electric currents causes this effect.

The generating surface of the electricity is at the meeting of the zinc and the liquid—the *electro-motive power*, as it is called, is exerted there. From this surface the positive excitement passes through the liquid to the copper plate, and thence along the connecting-wire back to the zinc; the negative passes from the zinc along the wire in the opposite direction towards the copper. There are thus always two opposite currents of equal intensity and quantity; but it is usual in speaking of the direction of a current, to notice only the positive electricity; when an arrow indicates the direction of an electric current, it is the direction of the positive current that is meant.

Two metal plates, with a liquid between them, form a simple voltaic combination; and when the unimmersed extremities of the plates are connected, either by leaning or bending the plates themselves, or by connecting them with a wire, the circle or circuit is said to be closed. The end of the system towards which the positive current is driven, is the *positive pole*, the other end, the *negative pole*. If the connecting-wire is divided in the middle, the same names are applied to the parts connected with the two plates respectively; the extremity of the part attached to the copper plate is the positive pole, or *positive electrode*, and that of the other, the *negative electrode*.

VOLTAIC PILES AND BATTERIES.

The first form of the apparatus for evolving chemical electricity was called the *pile of Volta;* because it was constructed by Volta from a great number of round pieces of metal, like crown-pieces, piled up in a column. If a round piece of zinc is taken, and a similar piece of copper, and if a moist cloth is laid between them, a voltaic circle will be formed when an outside conductor is carried from one plate to the other. All the four elements of the circle will be present: the zinc, a corrosive liquor in contact with it, and extending to the copper, the copper, and the outside conductor from the copper to the zinc. The cloth merely serves the purpose of containing the liquid. Thus, let an upright stand be formed, with glass or wooden rods fixed into a piece of wood for a bottom. Place on the bottom a disk of zinc Z; above that a piece of woollen rag soaked with corrosive liquor, of the same size as the zinc, and upon the cloth a disk of copper. On the copper lay another piece of zinc, a wet cloth, and another piece of copper; and repeat the same process until the pile is built up to a sufficient height, being careful to observe the same order throughout. The pile will terminate in a disk of copper above, and in a disk of zinc below; and when a conducting communication, such as a piece of wire, is carried from one end to the other, a circle will be formed, and a pair of currents will be carried round and round in opposite courses, exactly as in a single circle. Commencing at the lowest zinc plate, there will be a chemical action between its surface and the liquor touching it; electricity will be developed, the negative charge will pass upon the zinc plate, and the positive will be conducted through the liquid to the first copper disk, and from it to the zinc lying upon it, and thence to the place of action between the second zinc and the second cloth, where it will be reinforced by the excitement produced at this contact, and a double charge will pass through the second cloth to the second copper, and thence to the third zinc, to be reinforced again, and pass on as before. In this way all the actions of the pieces of zinc upon their adjoining liquid will conspire into one great positive current, passing from the bottom upwards; and at the same time the negative charges arising on the zinc plates will join together in one great negative current passing downward, and going off at the lowest plate by the outside conductor, and proceeding by it to the top, to move downward again. The general course of the process will be the very same as in a single circle: the zinc end will be the negative pole, and the copper end the positive pole.

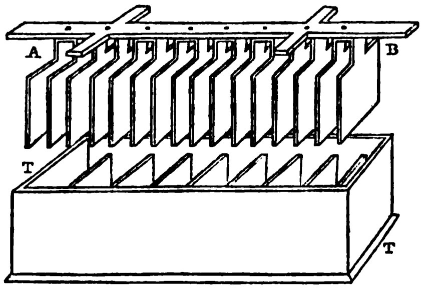


In the original arrangement of Volta there was a supernumerary plate at each end; a copper plate below the zinc at the bottom, and a zinc plate above the copper at the top. The top or positive pole was therefore called the zinc pole, and the negative pole the copper pole. The two extreme plates came afterwards to be removed as useless; and hence confusion has arisen in the designation of the poles.

The intensity of the pile increases with the number of plates. If these are few, but large, the intensity is not great, but the quantity is considerable. That is to say, such a pile would not give severe shocks, but it would have powerful magnetic and chemical effects, which, as stated, depend upon quantity, without regard to intensity.

The pieces of cloth employed in the pile being of no use but to contain the liquid, may be dispensed with, and instead of them, vessels may be used to contain both the liquid and the plates. Volta himself

made an arrangement of this sort; and all the usual forms of the voltaic battery are constructed on the principle of immersing the plates in the corroding liquor. The *trough-battery* is a procelain trough TT, divided by partitions into separate compartments or cells, each compartment being intended to receive a pair of plates



and contain the acting liquor. The plates are suspended from a piece of wood AB, at the proper distances for being immersed in the separate cells, and they are connected with one another by metallic slips; it being necessary that each plate of copper should have a conducting connection with the next plate of zinc, in order to complete the circle. No communication of any kind is allowed to take place between one cell and another: with this view the partitions are made not only water-tight, but of an insulating material like porcelain. The battery of the Royal Institution, by which Sir Humphry Davy effected the decomposition of the alkalies and earths, was of this construction, and consisted of 2000 pair of plates, with an acting surface amounting to 128,000 square inches.

THEORY OF THE VOLTAIC CIRCUIT.

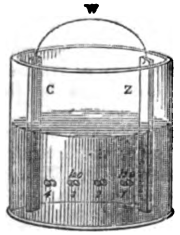
Various imperfections of a practical kind occur in the working of the piles and batteries above described, the most serious of which is, that the action, although ever so strong at first, becomes rapidly weaker and weaker, and in no very long time entirely ceases. The materials formed by the chemical action of the liquid and the zinc gradually accumulate, and stand between the fresh zinc and fresh liquor, and thus prevent the process from going on. But to remedy this and the other imperfections of the battery, it is necessary to understand clearly what the circumstances are that add to its strength, and what causes contribute to weaken and obstruct it.

Let us consider again a single pair of copper and zinc plates, immersed in a vessel containing liquid; and in the first place, let the liquid be pure water, which, though feeble in its effects, is an exciting substance. Let Z and C be the two plates, supposed to be seen edgeways, and to face one another, and connected outside by the wire W. It has been known for the last seventy years that water is not a simple, but a compound body, formed by the chemical union of two elements—oxygen and hydrogen. Each ultimate particle of water must therefore be supposed to be a compound particle, or an atom of oxygen adhering firmly to an atom of hydrogen. It is as a compound body that water acts in the voltaic circle, and as such we have to look upon it. Let the double circles 1, 2, 3, 4, stand for atoms of water, or compounds of oxygen and hydrogen; the oxygen atom being marked *o*, and the hydrogen atom *h*. An oxygen atom is supposed to be in contact with the zinc plate; and the process pursued is the following:—The zinc has, from its nature, a strong affinity for oxygen: this affinity is more powerful than the affinity of hydrogen for oxygen; and in such an arrangement as the present, the superior affinity of the zinc draws the oxygen atom to itself, dissolves the attraction between it and its hydrogen atom, sets the hydrogen free, and makes a new compound atom, called oxide of zinc. Along with this transference of the oxygen particle, there is a quantity of free electricity evolved: the oxide of zinc has a negative charge, and the disengaged hydrogen atom a positive charge. But this charge possessed by the hydrogen increases its affinity for oxygen, or makes it more powerful than a particle that has no such extra excitement. Accordingly, it approaches the oxygen end of the second particle of water, overpowers the affinity of the two atoms, combines with the oxygen, and sets the hydrogen free, charged in like manner with positive electricity. This free and charged hydrogen comes up to the third atom of water, and decomposes it in the same way; and a series of decompositions goes on till the copper plate is reached, and the action interrupted. Thus the free hydrogen appears at the copper plate, and communicates to it by contact its positive charge, rendering the copper positive, and enabling it to transmit positive electricity round the outside wire towards the zinc. The particles of free hydrogen rise up to the surface from the copper plate. The reason why the copper is not acted on in the closed circuit is, that the currents derived from the zinc overpower its own attraction for the oxygen of the water. The copper would of itself attract water-particles by their oxygen end, and decompose them; but the zinc being much more powerful in its attraction, it begins a series of decompositions that end in presenting hydrogen instead of oxygen to the copper, and in suspending its power to decompose the water. The transmission of electricity is thus effected by loosening the bonds of every compound atom that stands in its way, and by making up new combinations, where different atoms are brought together. The carrying round of the currents to the place of action quickens the energy of the combination at the surface of the zinc.

Such a circle formed out of zinc, copper, and pure water, would in a short time entirely cease, owing to the zinc becoming coated with oxide, which stands between the water and the particles of metallic zinc. But if a small portion of oil of vitriol, called also sulphuric acid, is poured into the water, it combines with and carries off the coating of oxide from the zinc plate, and leaves a clean surface; the action then goes on again with renewed energy. The acid continues to take up the oxide as fast as it is formed, and the circle is thereby rendered much more active.

When sulphuric acid combines with oxide of zinc, it forms a new substance, called sulphate of zinc, which remains dissolved through the liquid. But this new substance acquires, like the hydrogen, a positive excitement, and goes in consequence towards the copper, and is apt to form a deposit that mars the conducting power of the plate. Moreover, the hydrogen itself, by its attraction for the copper, is apt to remain stagnant on the surface, and prevent the evolution of new particles, on which the continuance of the action depends. This is remedied by pouring nitric acid into the cells, which has the power of absorbing the hydrogen as fast as it is formed at the copper; and to prevent the sulphate of zinc from going on to the copper conductor, a porous or permeable partition is interposed between the plates. This partition is called the *diaphragm*.

The power of a battery is increased by substituting for the copper a metal still less corrosive, such as silver, gold, or platinum. Platinum is, of all metals, the least acted on by acids; hence it is well adapted for the positive plate of the battery. Carbon is found even more



powerful. A further improvement is made by amalgamating the zinc plates—that is, coating them with mercury—which, from a cause not well understood, serves to diminish their waste.

Of the various forms of improved voltaic batteries, that known as *Daniell's Constant Battery* is perhaps the most effective and convenient. Each separate cell or circle consists of a cylindrical jar of copper, within which is placed another jar of unglazed porcelain, which allows the electrical excitement to pass through it. This inner jar contains diluted sulphuric acid, in which a rod of zinc is suspended; and the space between the jars is filled with a saturated solution of sulphate of copper. Here the current generated by the zinc passes through the porous diaphragm, towards the copper, while the sulphate of zinc formed by chemical action is confined. The hydrogen, again, set free at the surface of the copper cylinder, acts on the sulphate of copper in the solution, is absorbed by it, and displaces metallic copper, which is deposited on the cylinder. To renew the waste of the sulphate of copper, a few solid crystals are suspended, which dissolve gradually as they are required. Combinations of six, ten, &c., of these single cells are formed according to the power desired. The advantages of this system lie in the cheapness of the substances used and in the constancy of the action.

The strength of an electric current depends not only upon the activity of the excitement at the generating surfaces, but also upon the goodness of the conductors through which it has to pass. If the plates are far asunder, the depth of liquid between them obstructs and weakens the current. The wires also obstruct it in proportion to their length and thinness. The current passes most easily through a thick and short wire. The metals also differ greatly in their conducting power. A copper wire of 100 feet offers the same resistance as a silver wire of 136 feet, or an iron wire of 17 feet, all of equal thickness. The intensity of the electricity increases with the number of plates; hence, to transmit the current through a long circuit, a battery of many plates is used. The earth is often made to form part of the circuit, as in the electric telegraph.

EFFECTS OF VOLTAIC ELECTRICITY.

The voltaic current may produce heat, light, chemical decomposition, and mechanical power, as well as actions on the animal frame.

If a powerful pile is closed by a *thin* wire, which obstructs the passage of the current, the wire soon turns red hot. Even platinum, which cannot be fused in a furnace, yields to the voltaic pile, and iron and steel are melted and burnt. Gunpowder is now fired by this means in blasting rocks, &c.

The *light* producible by voltaic electricity is seen in the heated metals above described. A spark is also seen when the ends of the wires that close the circuit are in the act of joining or separating. But the greatest brilliancy of light is caused by making the wires end in pieces of charcoal, and bringing the pieces of charcoal together. If the pile is powerful, a brilliant stream, of an inch or more in length, may be made to pass from one point to the other. A stream of particles flows from the positive pole to the negative, leaving the end of the carbon of the former hollow, and that of the other conical.

The *chemical action* of the pile is the most important of all its effects. It was by its means that Sir Humphry Davy resolved the alkalies and earths into oxygen and a metal (see CHEMISTRY). Decomposition by this means is called *electrolysis*, and bodies which can be so decomposed are called *electrolytes*. It is only compounds of a simple kind that can be decomposed by the current; complex ones cannot. The compound must also be in the *liquid state* when the current is sent through it; ice cannot be decomposed, though water can.

When decomposition takes place, the elements always take a definite direction; oxygen goes uniformly to the positive pole, and hydrogen or a metal to the negative. Bodies that, like oxygen, go to the positive pole, are called *electro-negative*, and those that make their appearance at the other pole, *electro-positive*. The amount of decomposing force yielded by a battery is exactly equivalent to the amount of oxidation of zinc that takes place.

The *shock* of the voltaic pile differs from the discharge of a Leyden-jar; the electricity of the pile being of feeble intensity, it does not give the blow received from the jar. The greatest shock is derived from the pile of many plates. If, after moistening the hands in salt water, to heighten the conducting power of the skin, we grasp the two wires, one in each hand, a shock is felt at the first contact, and then a heating current up the arms, and a tingling sensation in the hands. A shock is also felt at the separation, arising from the sudden return of the polarised fibres of the arms to their natural state. When strong voltaic batteries are discharged through the bodies of animals recently dead, their limbs and features are convulsed and made alive in a hideous way. Experiments have been made on executed criminals, which shewed that electricity could in some degree act the part of the nervous currents in moving the bodily organs. By stimulating the nerves of the lungs, a laborious breathing was recommenced; by passing currents through the nerves of the face, the features moved and stretched themselves out into horrible grimaces; when one wire was connected with the hip and another with the heel, the leg, if bent, threw itself out with great force. In the same way, the fist could be closed, or the hand opened, by touching the proper nerves with one wire and the points of the fingers with the other. These results are only extensions of the original experiments of Galvani.

APPLICATIONS OF VOLTAIC ELECTRICITY.

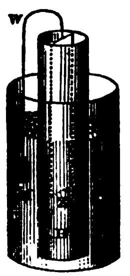
The first practical application of voltaic electricity to the arts, was the protection of the copper bottoms of ships from the destructive action of the sea-water. Sir Humphry Davy suggested that nails or wires of zinc should be fastened at intervals on the copper plates, which would cause a circuit to be formed of copper, zinc, and salt water. In this case the copper would cease to be acted on by the water, and would serve as a conducting plate to the zinc, which would be the substance wasted. Thus a small expenditure of zinc would come in place of a great expenditure of copper. A piece of zinc, equal to the head of a small nail, was found sufficient to protect between forty and fifty square inches of copper. The value of the application was, however, neutralised by a consequence which had not been foreseen. The protected copper bottom rapidly acquired a coating of sea-weeds and shell-fish, whose friction on the water became a serious resistance to the motion of the vessel, and it was discovered that the bitter poisonous taste of the copper surface, when oxidised, acted in preventing the adhesion of living objects. The principle, however, has been applied with success to protect the iron pans used in evaporating sea-water.

The greatest application of the voltaic circuit is the *Electrotype;* or the process of multiplying impressions of medals, coins, engraved plates, busts, &c., which was developed about the same time by M. Jacobi of St Petersburg and Mr Spencer of Liverpool. It is founded on what takes place in the circle of Daniell, where a solution of sulphate of copper is in contact with the copper plate, and deposits on it metallic copper. If the original plate were of a certain form, the deposited plate would exactly fit it; and if the latter could be taken off whole, its surface would be exactly the reverse of the former. If the one were a coin in relief, the other would be a coin with a hollow impression. As the copper is deposited in a shower of the finest particles, it must completely enter all the depressions and lines of the plate, and form a surface so faithfully exact in its correspondence, that no human perception could discern a

difference. The requisites of the process are, that the thing to be copied shall have a metallic surface, so that it may become the conducting plate of a circle—that something be done to prevent the coating from adhering too strongly to the original—and that the deposition should be so conducted that the deposited plate may have a close metallic texture.

The first discoverers confined themselves to the copying of metallic surfaces, such as copper-plates and coins; but a method has been found of copying plaster of Paris, wax, wood, or any non-conducting substance, by covering the surface with black-lead—a form of charcoal, which answers the purpose of a conducting plate.

The apparatus for copying a medal or coin consists of a cylindrical vessel, containing in it another cylinder of



porous porcelain to serve as a diaphragm. Thus, A is the outer cylinder; H is the diaphragm, which contains the zinc plate Z immersed in acidulated water. The outer space is filled with sulphate of copper, and in it hangs the original medal M, connected by an arching wire W with the zinc, and making a voltaic circle. The medal is covered over with wax or grease behind, and on the edges, or wherever the copper is not to be deposited. To prevent inseparable adhesion, the face is covered with a slight varnish. The action of the circle then precipitates copper on the naked surface of the medal, and goes on adding to it as long as may be desired. If the action is slow, the coating is so much the harder. To make a good impression of tolerable thickness, one or two days are allowed. If the hollow impression thus derived is put into the circle, and itself coated, a surface will be produced in relief, which will be a perfect fac-simile of the original coin. To save the double process of making first a hollow and then a relief, a cast of the original may be taken in wax or plaster of Paris, or other fusible material; this cast will then receive a surface of black-lead, or of fine copper bronze, which can be laid on with a brush. It is now a conductor, and may be inserted in the circle to receive a deposit, which will exactly resemble the original object.

To make gold or silver medals, solutions of salts of these metals must be substituted for the sulphate of copper.

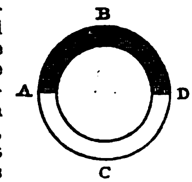
With a larger apparatus any number of copies may be made of an engraved copper-plate, and thus an unlimited supply of the finest impressions may be obtained.

Gilding and *plating* are now performed very successfully by voltaic deposition. Any metallic surface can be gilded or silver-plated, to whatever thickness may be desired. A platinum surface can also be communicated. In this way the precious metals can have their usefulness very much extended. Plants may, in like manner, be coated over with copper, and have their forms preserved for any length of time. So baskets and wickerwork can have a metallic surface communicated to them.

THERMO-ELECTRICITY.

Electricity of either kind produces heat, and heat, as we have already seen, can produce electricity. But it was only in 1832 that the means were found of producing a permanent current of electricity from heat. This discovery was made by Professor Seebeck of Berlin, and gave rise to the new science of Thermo-electricity or *heat-derived* electricity.

When two metals whose susceptibility to heat is unequal are soldered together, and heated at the joining, an electric current is evolved. Thus, if ABCD be a metallic circle, the one half, ABD, being *bismuth*, the other half *copper*, and if a lamp be applied at A, one of the joinings, it will heat both metals, and cause electric currents to flow round the circle. A positive current will pass from the bismuth to the copper, or round in the direction ACDB, the negative taking the opposite course. Thus, when two substances, differently disposed in regard to the reception of heat, are heated together at their point of contact, the discrepancy shews itself in the two metals polarising each other, and yielding electricity.



It is found that when hot water mixes with cold water, electricity is produced; the hot being negative, and the cold positive: and it appears that the passage of heat must in general cause electrical polarity. The following table exhibits the order of the principal metals in regard to thermo-electric combinations:—

Bismuth.	Platinum.	Copper.	Zinc.
Mercury.	Lead.	Silver.	Iron.
Nickel.	Tin.	Gold.	Antimony.

The further asunder two metals are in this table, the more powerful is the couple formed by them. Bismuth and iron would make the next best couple to bismuth and antimony. Each metal causes a positive current to pass upon any metal beneath it, and a negative upon any above it. The order of the metals above given does not correspond with their goodness as conductors of heat, nor exactly with any other property yet observed.

A series of bars of alternate bismuth and antimony soldered together, and then folded up in a bundle by bending, so that the first, third, fifth, &c., joinings will be at the one end of the bundle, and the second, fourth, &c., at the other, forms a compound electric circuit or thermo-electric pile. The bars are kept from touching at the sides by an insulating substance. The last rod of bismuth is connected with a wire, and forms the negative pole; and the wire attached to the last rod of antimony at the other end will be the positive pole. The two ends of the bundle are blackened to increase their absorption of heat. If either face is heated, a current will arise; if one is heated, and the other cooled, the current will be greater; if both are heated alike, there will be no current.

Such a bundle of bismuth and antimony needles has been constructed to serve as a thermometer for delicate experiments on heat. Differences of temperature, that are imperceptible by the mercury or alcohol thermometer, are found to affect the galvanometer of a thermo-electric pile. Radiant heat especially can be detected with extraordinary accuracy, by exposing one end of the bundle to the heating rays. By means of such an instrument the heat of the moon's rays has been made apparent.

MAGNETISM.

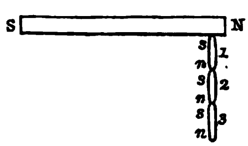
Anciently, there was found in Magnesia, in Asia, a certain kind of iron ore, in which the remarkable property was discovered of attracting other kinds of iron or steel: this ore afterwards received the name of *loadstone;* but from Magnesia, the place in which it was originally found, we derive the terms *magnet* and *magnetism.*

Besides attracting iron, the loadstone is found to have the remarkable property named *polarity;* that is to say, if a loadstone is freely suspended by a string, or lies on a pivot, it will not rest till it has settled in one position, which is a nearly north and south direction. If it be moved out of this position, it returns to it again. The term *polarity*, which has now such a wide usage in the sciences, originated in this fact. The end of the loadstone that pointed to the north pole of the earth was called its north pole, and the other end its south pole; and the loadstone was thus said to be *polar.*

But the loadstone, besides attracting iron, and pointing to the north and south poles of the earth, has the power of communicating its virtue to steel. If a bar of steel is repeatedly rubbed from end to end by a loadstone, the steel is permanently endowed with all the magnetic properties; that is, it is able to attract iron, and it arranges itself in the north and south direction. A piece of steel thus acted on is called an *artificial magnet*, the loadstone being designated the *natural magnet*. A magnet will attract iron in all its forms; but it is only iron made into steel that can take on the power of magnetising upon itself.

If we suspend a magnet till it come to rest in its north and south position, the north end is always reckoned its north pole; and this is a test for discriminating the poles. If, now, we take two magnets whose poles are known in this way, and if we present the north pole of the one to the north pole of the other, we shall find that they repel one another. But if we bring the *north* pole of the first near the *south* pole of the second, they attract each other, and cling together, end to end, and the one will draw the other after it. Hence are deduced the two general facts, or general laws of magnetic polarity—namely, *like poles repel each other; unlike poles attract each other.* We have seen that electrical attractions follow the same laws. Wherever polarity occurs—that is, whenever bodies have opposite forces residing in their opposite sides—it is on these principles that the attractions and repulsions take place.

The attraction of magnets for unmagnetised iron arises from a temporary communication of magnetism, called *induction*. This action is best understood by taking a few short pieces of iron wire and suspending one of them to a pole of the magnet. By this suspension it is made a magnet for the time, and two active poles are developed in it. If the north pole of the magnet is used, the wire 1 will have its upper end a south pole, and its lower end a north pole, ready to attract iron, as if it were a permanent loadstone. Bring now the wire 2 into contact with the first. The active north pole of No. 1 will develop an active south pole in the upper end of No. 2, and an active north pole at its lower end; the unlike poles will attract each other, and the second will hang by the first, and will have the power of communicating the same polarity, and exercising the same attraction for a third wire. The weight of wires that can be polarised and suspended is limited by the power of the magnet.

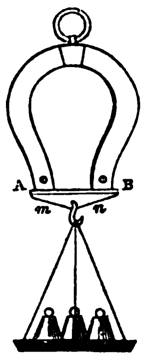


The instantaneous influence of a magnet on a bar of steel is not nearly so great as on one of soft iron; the steel resists the induction, and it requires motion and friction to magnetise it thoroughly; but when once rendered polar, steel *retains* its polarity.

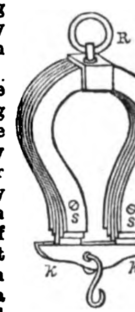
There are only a few substances capable of acquiring magnetism, either permanently or temporarily; these are the nine metals, iron, nickel, cobalt, manganese, titanium, cerium, palladium, and platinum, together with oxygen.

If a rod of copper is suspended horizontally between the poles of a horseshoe-magnet, it is repelled by both poles alike, and assumes a cross or equatorial position. This curious property, discovered by Faraday, and called *diamagnetism*, or cross-magnetism, is decidedly marked in the metals antimony, bismuth, copper, gold, lead, mercury, silver, tin, zinc; but it also belongs to almost all non-magnetic substances, solid, liquid, or gaseous.

A straight bar of steel, magnetised by rubbing, is called a bar-magnet. But it is more convenient to give magnets the form of a horseshoe, which brings their poles near each other, and makes it easy to complete the circle, and to bring both poles into play upon the same object. Such a magnet is represented in the following figure. A and B are the two poles; they are joined by the bar *mn*, which is of course polarised; *m* having the opposite magnetism from A, and *n* from B. Each horseshoe-magnet is permanently furnished with such a cross-piece, made of soft iron, which is called the *keeper*, and sometimes the *lifter*, and also the *armature*. When the magnet is used to suspend weights, these are attached to the keeper, as shewn in the figure.



In order to make a very powerful magnet, a number of single bars are joined together. This makes a *compound magnet*, or a magnetic bundle or battery. They may be either straight or horseshoe bars. A compound horseshoe-magnet is represented beneath: R is the ring for suspending it, and *kk'* the armature; the bars are magnetised before being joined, and they are fastened by screws *s* and *s* running through them.



The strength of a magnet may be gradually heightened by hanging weights to it, which are to be increased at intervals of time by little and little. On the other hand, the magnet is weakened by abruptly breaking the contact, as in drawing off the keeper suddenly. If an iron bar is in inductive contact with a magnet, and in that position receives a succession of blows with a hammer, it will acquire a fixed magnetism: so, if it is placed under induction while hot, and allowed to cool, the magnetic state will be confirmed so as to remain; also if iron, while under induction, becomes rusty, the chemical action will have the same effect in fixing the magnetism. On the other hand, a magnet when heated to redness, and then cooled, loses its magnetism entirely, as well as its steel temper.

Magnetism of the Earth.—The earth, taken as a whole, forms a great magnet, having two poles, termed its *north and south magnetic poles.* This is the cause that a magnetic bar or needle, when suspended, assumes a position nearly north and south. The exact direction of the needle at any place is the *magnetic meridian*, and the angle it makes with the true meridian, is the *declination* of the needle. This declination, or *variation* of the needle, as it is also called, is sometimes east, and sometimes west. It varies in different places, and for any one place it is generally undergoing a steady and progressive change. At Paris, for instance, in 1580, when observations first began to be recorded, the declination was 11° 30′ east; from which time it gradually decreased till 1669, when it was 0°—that is, the needle pointed due north. In 1700, it was 8° west, and went on increasing till, in 1814, it reached the maximum of 22° 34′; since then, it has been gradually diminishing, being, in 1835, 22° 4′. The present declination in England is about 24°; but it has been diminishing since 1815. The average declination for Europe is 17°, it being less as we go eastward; at St Petersburg, it is 6°; Iceland, 38°; Greenland, 50°.

It is evident how important it is for navigation that these changes of declination at different places on the ocean should be accurately known and marked on the charts. Lines drawn through all places that have the same declination are called *isogonic* lines—that is, lines of equal angles. There are two lines on the earth's

surface, one in America, the other in Asia, on which there is no declination; they run nearly north and south, but do not follow the course of meridians. They are slowly changing place, the Asiatic one advancing towards Europe.

Besides this general movement in one direction, the needle shews other variations: it has a small daily vibration, called the *diurnal variation*. From sunrise it begins its westerly sweep, which continues till about five P.M.; it then retrogrades, and continues to move east until it has reached its mean position, where it settles through the night.

If a bar or needle is made to balance itself level or evenly on an axis before being magnetised, it will not lie even, if placed in the magnetic meridian, after it has been rendered a magnet. It points downward, or is said to *dip*. This dip or *inclination* of the needle is so great in some places as to make it stand nearly upright. But the dip varies with the latitude. Near the equator, the needle is nearly level; in the regions about the north and south poles, it approaches the upright position. In this country, it inclines or dips about 70°. Captain Ross came to a place in 70° 5′ north latitude and 263° 14′ east longitude, where the needle stood perfectly upright, shewing that the north magnetic pole was directly under that spot, being thus at a considerable distance from the north pole of the earth. On the other hand, there are places in the tropics where the needle has no inclination; and every such place is said to be in the *magnetic equator*, which is formed by drawing a line through all the points where this perfect level occurs. The magnetic equator does not coincide with the earth's equator, but deviates to each side of it, and forms on the whole a very irregular line. The level of the needle is evidently produced by the equal and opposing actions of the north and south poles. North of the magnetic equator, the dip is north, and south of the equator it is south.

There is the same constant fluctuation in the inclination as in the declination of the needle. The inclination has been gradually diminishing in London for the last century. It also has daily variations. The aurora borealis has always an effect upon the magnetic needle, both in its declination and its inclination. Earthquakes and volcanic eruptions are accompanied with magnetic disturbances, which sometimes cause a permanent alteration of the needle. There occur, besides, agitations, called magnetic storms, which sometimes affect a whole continent simultaneously, and produce large vibrations in all the magnetic instruments. From all these circumstances, it appears that the earth's magnetism is undergoing incessant fluctuations and changes, some gradual and steady, others sudden and momentary.

Besides the inclination and declination caused by the earth's magnetic polarity, the *intensity* of the action has been made a matter of observation. This is measured by a separate instrument, and it is found to be least on the magnetic equator, and to increase gradually towards the magnetic poles; but, like the other two elements, it is continually varying in the same place.

In regard to inducing magnetism upon iron, the earth acts like an ordinary magnet. A bar of iron, pointed to the pole like a dipping-needle, and hammered, or cooled, or rusted in that position, becomes a magnet. So certain is this effect, that hardly any iron is ever found free from magnetism. The earth's inductive effect is rendered permanent in pieces of iron by the various modes of working and employing them, as well as by the spontaneous oxidation which occurs when they are lying unused. In high north latitudes, pokers and bars that usually stand on end inevitably acquire a small degree of magnetism. In the tropics, bars which lie on the ground nearly north and south are affected in a similar way.

The Mariner's Compass.—In using a magnetic needle as a mariner's compass (see MARITIME CONVEYANCE), to guide navigation in the open ocean, which is one of the most important applications of magnetism, a difficulty arises from the action of the iron used in building the ship upon the needle, more especially in ships altogether composed of iron. The deviations thus caused are corrected by so disposing masses of soft iron and magnetic bars near the compass, as to counteract the effect of the more distant mass of the ship. If it were merely as soft iron that the metal of the ship acted, these corrections would be less difficult; but through the inductive influence of the earth, as above explained, the iron becomes permanently magnetic, and this induced magnetism is liable to be altered by concussions and strains, according to the position of the vessel with respect to the magnetic meridian. The action of the compass thus becomes, without warning, sometimes seriously deranged, and leads to danger and shipwreck. Recent experiments seem to lead to the conclusion, that the most effectual protection for the compass, from these derangements, is to place it at a considerable elevation above the deck.

ELECTRO-MAGNETISM.

This branch of electricity was created in 1820, when Professor Oersted of Copenhagen discovered that a voltaic current has the power of magnetising an iron bar, so as to give to it all the properties of the loadstone. This discovery, taken along with thermo-electricity, completes the proof of the identity of the various natural agencies known by the names of chemical affinity, heat, electricity, and magnetism. All these influences are nothing more than modifications of one grand power pervading material bodies, and most probably derived from the sun. It is not necessary that they should be supplied separately to the earth; for out of any one of them all the others can be produced.

It had long been observed that electricity was capable of producing magnetic effects. The needles of ships' compasses, when struck with lightning, always underwent a change in their magnetic character: on some occasions their poles have been reversed, what was the north before becoming the south. Disturbances of needles have also been caused by shocks from Leyden-batteries. It was thus generally supposed that an intimate connection of some kind subsisted between electricity and magnetism. The discovery of the real nature of this connection was reserved for Oersted.

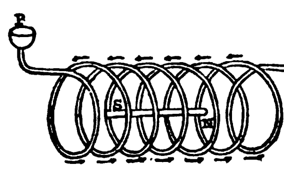
If a magnetic needle is held along the conducting-wire of a voltaic circle in action, it is made to deviate: if it is suspended along and *above* the wire, it instantly turns about and hangs directly across it: if it is next hung along and *beneath* the wire, it will deviate and lie across, but the ends will be the reverse of the former case—the end that went to one side of the wire is now on the other side: if the needle is hung along the wire *at one side*, or in the same horizontal plane, it dips; one end falling beneath the level of the conducting-wire, the other rising above it: if carried to the *other side* of the wire (without being reversed), it dips in the same way, but the pole that was down is now up. Thus it appears that a voltaic current has the power of acting on a needle; but that this power lies not in the direction of the wire, but *across it*. It is as if a magnetic power encompassed or circulated round the channel where electricity flows; or as if a particle, in receiving and transmitting the electrical polarity, acquired also a pair of magnetic poles and a magnetic axis, lying directly across the electric axis.

The connection between positive and negative currents, and north and south poles, is somewhat puzzling to remember. It may be stated thus: If a positive current passes along a wire before the breast from right to left, the head would represent the north pole of the attracted needle, and the feet the south pole; if the current flows in the opposite direction, the poles are reversed.

If the wire of an electric circuit is thus a magnet, it ought to shew attractions and repulsions for other electric wires. This actually takes place. If the wires of two circuits are laid alongside of each other, and are free to move, they are mutually repelled, if the direction of the current is the same in both, and attracted, if the currents are contrary; so that without the mediation of a steel-magnet, the forces circulating round the wires are able to shew themselves.

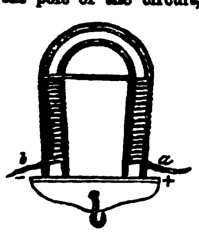
A needle of soft iron, laid across a conducting-wire, lies in the wire's magnetic direction, and is magnetised by induction. But the action of a single straight wire upon an iron rod would be very feeble. If, however, we bend the wire round the rod, and coil it again and again, we increase the amount of the magnetic circles which act on the iron. Instead of an inch of wire communicating its influence, we may have the inductive force of many feet, and a very powerful magnetism will be imparted. It is by coiled wires, therefore, that electro-magnets are formed. A spiral coil is technically called a *helix*. Such a form possesses all the powers and properties of a magnetic bar when the electric current passes through it. It attracts and repels other magnets, communicates temporary magnetism to soft iron by induction, and permanently magnetises steel.

A striking effect of the attraction of a magnetic bar by a helix is shewn in the figure, which represents a coil ending in two little cups P and *p*, where the communications



are made with the poles of the battery; a small portion of mercury is poured into each cup, and the battery-wires are dipped in the mercury, which thus forms a very perfect metallic junction. If a magnet SN is laid in the coil, and the circle completed, the action is such that the magnet starts up and suspends itself in air in the centre of the hollow, and hangs there as long as the electricity circulates. The opposing actions of the different ends and sides of the wire so neutralise each other, that it is not drawn either out or in, or nearer to one side than to another; and its only position of rest is a nearly central station: its own weight necessarily adds to the downward tendency, and keeps it a little below the axis of the spiral.

In communicating temporary magnetism to a soft iron bar, with the view of forming the electro-magnet, we may choose either a straight bar or a horseshoe: the latter is represented in the figure. The wire *a* from one pole of the circuit, is coiled round and round the iron many times, and goes off at *b* to join the other pole. If the positive current pass in at *a*, *a* will be the north pole of the magnet, and *b* the south, according to the rule already laid down. To make a powerful magnet, the copper wire should be thick, and covered with silk, to prevent the electricity from passing sideways from one coil to another, or to the iron bar. A lifter is attached for the suspension of weights. An electro-magnet may be made of far greater power than an ordinary magnet of the same size. A horseshoe whose arms are eighteen inches long, and two inches thick, may be made to sustain 1000 pounds if a strong current is passed through it.



An electro-magnet loses its polarity the instant the voltaic current ceases to flow; but if a steel needle is laid inside of a helix, and a strong current passed along, it will acquire permanent magnetism.

The *galvanometer*, or voltaic electrometer, is formed on the principle of making the current whose strength is to be measured flow parallel to the direction of a magnetic needle, and observing how far it deflects the needle from its position.

Cause of the Earth's Magnetism.—On the principle explained under the head of Thermo-electricity, electric currents will be excited at that part of the earth's surface where the sun's rays are most powerful for the instant, and will circulate round the earth from east to west. The globe is therefore in the circumstances of a coil round which an electric current is flowing, and must manifest magnetism in the direction of its axis. It is thus a great electro-magnet.

ELECTRO-MAGNETIC MACHINES.

If an electro-magnet is so arranged that when not active the lifter rests a short distance apart from the ends of the horseshoe, when the current is made to pass, the lifter is drawn up with a force depending upon the power of the magnet, which may amount to tons. On again breaking the circuit, the lifter falls away, to be again attracted on re-establishing the current. It is obvious that this alternate rise and fall of the lifter may be made a moving power in mechanics, similar to the piston of a steam-engine. Accordingly, electro-motive power is sometimes employed to give motion to machines, as in the workshops of M. Froment, the mathematical instrument-maker in Paris.

Electric Telegraph.—But by far the most important application of voltaic electricity is the electric telegraph, invented by Wheatstone, and perfected by him and others. The electric telegraph, in its various forms, depends upon the power of the voltaic current of being conveyed to a great distance, and there producing effects which can be so regulated as to compose a set of signals, or a conventional alphabet. The electricity is generated in a trough-battery adapted for the purpose. The current passes from one end of the battery along a line of conducting-wire suspended on poles, to the place to be communicated with. On the first introduction of the telegraph, a return-wire was used to complete the circuit; but it is now found that the earth can form the returning part of the circuit, so that a single line of wire suffices. At each end, the wire is carried down to the ground, and attached to a large plate of metal buried there, and the current passes through the moist earth from plate to plate. The wire is of iron, galvanised, or coated with zinc; it rests on the poles in glass or earthenware tubes, to insulate the passing electricity.

Both the magnetic and chemical effects of the current have been made use of as telegraphic signs, but chiefly the former, so that the telegraph may be considered an electro-magnetic machine.

We have seen that when a current passes over a magnetic needle, it deflects it from its position of rest—the deflection being to the right or left, according to the direction of the current. Now, by breaking and renewing the contact of the wires, the current can be set on and interrupted at pleasure; and by changing the ends of the battery with which the wires are connected (through a contrivance called a *reotrope*, or commutator), the current may be instantly reversed. Thus, a person in London, by simply swaying a handle to right or left, may cause a needle in Edinburgh to move to right or left. It may then be agreed upon that a deflection to the right shall signify the letter A; one to the left, B; two motions to the right in close succession may mean C; and so on for any number of repetitions. It is found convenient to have two or more needles, each with its own wire; and by combining their motions, an alphabet is made out without too many repetitions. This is the nature of the *needle-system* of signs generally employed in England.

Morse's system, used in the United States and

elsewhere, depends on the power of the electric current to render soft iron a temporary magnet. Such a magnet is made to act on a lever, that regulates the motion of a pencil, under which a slip of paper travels with a regulated velocity guided by clock-work. When the current is set on, the pencil presses on the paper; when it is interrupted, the pencil is raised. It is evident that a succession of dots, lines, and intervening blank spaces, of any length, may thus be formed at pleasure; and these can be interpreted according to the conventional meaning attached to them.

In the *electro-chemical* telegraph of Mr Bain, a metallic point is made to travel on a sheet of paper moistened with a chemical solution. When contact is made, the current passes from the point through the moist paper to the metal plate on which it lies, and in passing decomposes the chemical solution, leaving a coloured spot. If the current is maintained, a line is traced; and thus dots, lines, and blanks may be produced in coloured ink, as it were. With this system, according to Dr Lardner, 20,000 words can be sent 1000 miles in an hour.

The galvanic principle has also been applied to the movement and regulation of clocks. (See HOROLOGY.)

MAGNETO-ELECTRICITY.

Magneto-electricity is the counterpart of electro-magnetism: the one explains the production of magnetism by an electric current; the other shews how an electric current may be produced from a magnet. This branch of the science was created by Professor Faraday.

Since a helix charged with a current can magnetise a bar lying in it, if we take a bar-magnet and put it into a coil which has no connection with a voltaic circuit, we should naturally expect an electrical current; but no current is observed. Let us, however, seize hold of the magnet, and instead of its lying at rest in the hollow of the coil, let it be moved backwards or forwards; a current is immediately produced, the needle of the electrometer being sensibly deflected. The electricity arising from this action is called Magneto-electricity.

If an active wire, in connection with a circuit, lies alongside of another wire that is inactive and connected with a galvanometer, the current of the first has no influence in making a current in the second while both wires are at rest; but at the instant the current is arrested, and the instant that it is set on upon the first wire, a momentary current appears on the second. While the current continues, there is no action. Let, however, the wires be made to approach each other, and a current ensues on the inactive wire; when the wires are at a stand-still, it ceases. Or if they are drawn away from each other, a current in like manner arises, but opposite to the current during the approach: so that there are two methods of passing a current from an active to an inactive circle. We may either close or break the active circle, and thereby create an instantaneous current; or we may move the wires nearer or further from each other, and during either motion we have a current on the inactive circle; the approach making it in one direction, the recession making it in the opposite direction. These effects are designated by the term Volta-electric Induction; and the currents, Induction Currents.

The approximation or separation of the wires is exactly similar to the moving of the magnet in the coil, or across a wire. An active wire is a magnet, and if it is moved sideways towards another wire, the effect is the same as if a magnetic bar were moved endways. The side motion of the one, can do exactly what the longitudinal motion of the other can do. In both cases, mere proximity has no effect; but, by movement, each can excite a current in a dead circle.

By making a plate of copper revolve with its edge between the poles of a magnet, Faraday was able to produce a permanent electric current. The shock given by an induced magneto-electric current is more severe than that of a primary current. Magneto-electric machines for medical purposes are contrived so as to give the current a character of rapid intermission, which increases its effect.

ELECTRICITY OF ANIMALS AND VEGETABLES.

The most striking case of electricity produced by animals, is that of certain fishes, of which the *Torpedo* and *Gymnotus Electricus*, or electrical eel, are the most remarkable. These animals have special organs, of a large size, consisting of a number of cells, in which the electricity is generated as in a galvanic pile, but by what particular action is not understood. The upper side of the torpedo is positive, and the under negative, and the discharge is sent from the one to the other through the surrounding water, and whatever conductor intervenes. The discharge seems under the control of the will, and the animal by repeated shocks can stun its enemies and its prey.

But apart from the possession of special organs, the vital functions generally seem to be attended by the development of electricity. It has been proved by Matteucci and others, that both in living animals and in those recently killed, there is always a current circulating from the interior of a muscle to its surface. In this way, by placing a number of half thighs of frogs one upon another, is formed a *muscular pile*, capable of producing sensible effects. The surface of the human body is generally in a positive condition; but fatigue, exhaustion, and cold are said to produce a negative condition.

The effects of a voltaic current sent through the nerves are remarkable. It produces contractions of the muscles, and convulsive motions of the limbs. The bodies of men and animals recently deprived of life, are thus thrown into a state of violent activity resembling life. Suspended animation has thus occasionally been restored. When the current traverses any part of the optic nerve, a sensation of light is produced; similarly, the effect on the nerves of hearing is to excite the sensation of sound; and so with the other senses.

If a current continue to pass along a motor nerve for some time, the nerve loses its excitability; but this is restored by reversing the current. The chief effect is always produced at the beginning and end of the contact. From these and similar facts, it was not unnatural to suppose that the nerve-force, or nervous energy, may be nothing else than an electric current. Careful examination, however, disproves this; no indications of an electrical current can be detected in the nerves of living animals, nor indeed does the arrangement seem to admit of it, there being no appearance of a closed circuit. But though not identical, the two forces are analogous, and intimately related, similarly to heat and electricity. 'The development of electricity by a crystal of tourmaline when heated, clearly proves the relation between heat and electricity: a similar relation between the nervous force and electricity is demonstrated by electric fishes. Electricity is not, however, the nervous force, any more than *heat* is electricity: the one changes into the other in the one case, by the form of the integrant molecules of the crystal; and in the other, by the structure of the electric organs.'

Recent researches would seem to establish the fact, that the process of vegetation also excites abundance of electricity. Currents are said to be detected in all parts of vegetables. The result of one set of experiments is, that 'the roots and all the interior parts of the plants filled with sap, are permanently *negative*, while the moist surfaces of the fresh branches, leaves, &c., are permanently *positive*.' It is not unlikely that vegetation thus exercises a powerful influence on the electrical condition of the atmosphere.

CHRONOLOGY—HOROLOGY.

THE general relation of events and successive existences to each other we denominate *Time*—a thing of duration, involving the past, the present, and the future. It is evident that for the measurement of time we can have no standard of the same tangible nature with a pound, a yard, or a pint measure. We must have recourse to the space or duration involved in some continued or reiterated *motion*, as to which we have all the proof possible in the nature of the thing, that it requires the same period for its recurrence on one occasion as on every other. The motions of the heavenly bodies are of such a nature, and present the surest standard of reckoning time on a large and comprehensive scale. For periods, however, less in duration than a single day, or day and night, there are no explicit natural standards; hence the utility and necessity of mechanism of human invention, the motions of which, mathematically adjusted and numbered, shall measure and record more brief and arbitrary divisions.

In accordance, therefore, with what is the common practice of mankind in applying such a scale of time to the general routine and business of life, especially in its more civilised condition, we purpose to treat—*first*, of the measurement of time by days, months, years, and cycles, considered with special reference to their respective natural and artificial subdivisions and accumulations; and, *secondly*, of those instruments and machines which have been invented for dividing the leading astronomical unit, or day, into seconds, minutes, and hours. The former of these departments may be termed *Chronology*, or the science of time in general; the latter, *Horology*, or an explanation of the various contrivances which have been devised for marking and measuring its arbitrary subdivisions.

CHRONOLOGY.

Chronology—from *chronos*, time, and *logos*, discourse—is literally the doctrine of time; the science which treats of its various divisions, and of the order and succession of events. The chronologist has thus a threefold duty to perform—namely, to assign a measure to the interval which elapses between the recurrence of any natural event; to determine certain points or epochs from which to date occurrences, whether preceding or succeeding that epoch; and, lastly, dating from any given epoch, to arrange in due order all facts and phenomena which may be considered of importance. Adopting this course, we shall treat, in the first place, of the division of time into

DAYS AND HOURS.

The day is that portion of time which elapses while the earth turns once completely round on its axis—one half of its surface being exposed, alternately, to the light of the sun on the one hand, and to the darkness of the starry heavens on the other—thus producing to those carried round with it the succession of day and night, and the apparent phenomenon of a diurnal revolution of the sun from one point in the illuminated atmosphere back again to the same point, or nearly so, as explained under ASTRONOMY.

The succession of day and night would undoubtedly constitute the first great natural period reckoned by the human race—involving, as it does, not only the most familiar and most strikingly contrasted phenomena within the bounds of man's experience, but phenomena peculiarly adapted to the great necessities of his nature—those of vigilance and sleep. Yet the precise point at which the day should be held to begin and terminate, must have been a matter much less easily settled; and accordingly we find, that while amongst ancient nations—the Babylonians, Persians, Syrians, Greeks, and almost all the nations of Asia—the day began at sunrise, and was held to last throughout the whole of the ensuing daylight and darkness—an arrangement better adapted to countries near the tropics than elsewhere, as the sun there rises more nearly about the same time throughout the year—the Jews, Turks, Austrians, and others, with some of the Italians and Germans, have begun their day about sunset; the Arabians theirs at noon, as do astronomers and navigators of all nations; the ancient Egyptians, and most of the modern Europeans and Americans, on the other hand, as well as the modern Chinese, beginning theirs at midnight, which is evidently the most convenient method, since it throws all the waking and active portion of the day under one date.

The subdivision of the day into morning, forenoon, mid-day, afternoon, evening, and night, is natural, though somewhat indefinite, and may be conceived to have always been more or less marked by man, even in his rudest state. At all events, the ancient Chaldeans, Syrians, Persians, Indians, Jews, and Romans, divided the day and the night into four parts; but there is nothing obvious in the natural changes or motions of the sun, moon, earth, or stars, which could point out the division of days into hours, hours into minutes, or minutes into seconds. These divisions are entirely artificial and arbitrary, unless, indeed, we conceive the second to represent that minutest portion of time which, to the human mind, constitutes its natural unit or rudiment, as particles constitute the units of a mass; but even seconds have been subdivided into thirds; and still it is evident that, after all, these are no more the minutest elements of time than are molecules the minutest elements of masses.

In the civilised part of the world, it is now customary to divide the day, and reckon the minuter portions of time, by instruments to be afterwards described, in seconds, sixty of which constitute a minute; in minutes, sixty of which constitute an hour; and in hours, twenty-four of which constitute a day. Most nations have these instruments marked for only twelve hours, the computation being twofold, like the day itself; but the Italians, Bohemians, and Poles, run them on from the first to the twenty-fourth—from one o'clock to twenty-four o'clock. The Chinese, on the other hand, divide the day into twelve hours only, each being, therefore, twice the length of ours. When the decimal system was adopted by the French, the day was necessarily divided into ten hours.

The length of time which elapses while any given point on the earth's surface passes from its corresponding point in the starry firmament, and returns to the same point, is called the *sidereal* day, and is found, when measured by the motions of the ordinary instruments invented for the purpose of pointing out its subdivisions—namely, time-keepers—to consist of, or be equal to, 23 hours 56 minutes 3 seconds, and (to be still more exact, as astronomers require to be) 4 thirds—a third being the sixtieth part of a second. But although the distance of any fixed star in the firmament is so immense, that the whole orbit of the earth is but, as it were, a point itself in comparison, and the motion of the earth in that orbit, therefore, cannot alter or affect the length of the sidereal day to any appreciable extent, it is otherwise

with the *solar* or natural day, which is that portion of time elapsing between the arrival of the sun at the meridian, or mid-day, on two consecutive days. The mean length of this period of time is twenty-four hours; nearly 3 minutes 56 seconds on the average being required, in consequence of the earth's motion in its orbit, to bring the sun up to the same meridian on every successive day. The inclination of the plane of the earth's equator to the plane of its orbit, however, and the unequal rapidity of the motion of the earth in its orbit, really cause the solar or natural days to be of unequal length; so that, though averaging twenty-four hours each, they sometimes fall short, and sometimes exceed that average. (See ASTRONOMY.)

We have thus three species of day—the sidereal, or that time which elapses between two successive culminations of the same star, and which is now universally adopted by astronomers in their observatories; the solar, natural, or apparent day, being the time that elapses between two consecutive returns of the same terrestrial meridian to the centre of the sun, and which consequently commences at noon; and the civil or mean solar day, which is the mean or average of these meridional returns, and which most modern nations have adopted, placing the commencement and termination at mean midnight.

It is here necessary to observe, that as the earth rotates from west to east, every meridian has its own natural day; and any place east or west of that meridian has a corresponding earlier or later sunrise. The earth, of 360° of longitude, turns in twenty-four hours; consequently every hour is equal to 15°; and every degree equal to four minutes of time. Thus, taking Greenwich as the normal meridian, Alexandria being 30° east, is two hours earlier, or has it twelve o'clock when it is ten at Greenwich; Bengal is 90° east, and it is there twelve at noon when only six in the morning at Greenwich. So New York is 74° west, or 4 hours 56 minutes; and consequently, when noon at Greenwich, it is only four minutes past seven in the morning at New York. As with these large distances, so with every other difference of longitude, however minute; and it is thus that we speak of our clocks being earlier or later than Greenwich time, according as we are situated east or west of that meridian. Ipswich, for example, being east of Greenwich, is about five minutes before, or earlier; Edinburgh, being west, is about twelve and a half minutes behind; and Dublin, being still further west, is about twenty-five minutes late. Hence the necessity, in these days of rapid transit, of keeping by one uniform standard of time, or at least of having a table of differences for the principal stations throughout the country. In most cases, it would be preferable to have our clocks furnished with two minute-hands—one to indicate Greenwich time, and the other the natural time of the locality.

MONTHS AND WEEKS.

After the day, the next distinct natural measure or division of time marked out by the heavenly bodies in their time-keeping revolutions, is the month. The lunar month is the period during which the moon revolves once round the earth, and is equal to 29 days 12 hours 44 minutes 3 seconds. The solar month is the period during which the sun appears to pass through a twelfth part of his annual course, or through one of the twelve arbitrary signs of the zodiac, and is equal to 30 days 10 hours 30 minutes: it is not so distinctly pointed out by nature as the lunar month. The month came ultimately to be disconnected from the lunar and terrestrial revolutions, as will be afterwards more particularly noticed, and civil or calendar months, accommodated to the year, were substituted; these also, as well as the names given to them in their annual order, will fall to be noticed while treating of the year itself and its subdivisions.

The subdivision of the month into weeks of seven days is very ancient, having, from the most remote period of history, been in use among the Hindoos and other nations in the East, including the Chaldeans and Jews. The week did not enter into the calendar of the Greeks, who divided the civil month into three periods, of ten days each; and it was not introduced at Rome till the time of the Emperor Theodosius. The Roman month was anciently divided into three periods—*Calends*, *Nones*, and *Ides*. The calends were invariably placed at the beginning of the month; the ides at the middle of the month, on the 13th or 15th; and the nones (*novem*, nine) were the ninth day before the ides, counting inclusively. From these three terms the days were counted backwards in the following manner:—Those days comprised between the calends and the nones were denominated *days before the nones;* those between the nones and ides, *days before the ides;* and those from the ides to the end of the month, *days before the calends.* The Greeks had no calends; hence the Roman phrase *Græcæ calendæ*, or 'never,' corresponding to the English 'Latter Lammas,' and the Scotch 'Morn come never.'

The use of weeks is supposed by some to be a remnant of the tradition of creation; by others, as suggested by the phases of the moon; while a third class refer its origin to the seven planets known in ancient times. The latter hypothesis explains the circumstance, that the days of the week have been universally named after the planets in a particular order. Thus the French, at the present day, following the practice of the ancients, name the days from Mercury, Jupiter, Venus, &c.; while the English adopt Saxon appellations, derived from the deities of Northern Europe, and from the sun and moon. Hence our term Sunday is from the *Sun;* Monday, the *Moon;* Tuesday, *Tuesco;* Wednesday, *Woden;* Thursday, *Thor;* Friday, *Friga;* and Saturday, *Seater.* (See SUPERSTITIONS.) In England, the Latin names of the days are still retained in legislative and judiciary acts. The Quakers, or Society of Friends, do not use the name of the week-day, but call each day, as they do the months, by its proper number—reckoning Sunday the 1st, Monday the 2d; and so on.

YEARS AND SEASONS.

The year, properly so called, or the solar or astronomical year, is that portion of time which elapses while the sun passes through the twelve signs of the zodiac, or rather, while the earth revolves once completely round the sun in its orbit; and while, from the parallelism of the axis of the earth's rotation to itself, combined with its inclination to the axis of the orbit, each hemisphere is turned alternately, once toward, and once from the sun; thus constituting, at least in the extra-tropical regions, the distinction between summer and winter. (See ASTRONOMY.)

The distinction of the seasons would soon be found to depend upon the alternate approach and departure, or elevation and depression, of the sun in the heavens at stated and regularly recurring intervals; but the exact division of time into solar years could not have been effected till astronomy had made some progress; when it would immediately appear, in the endeavours at length made to measure the year by revolutions of the moon, that as an exact number of days, or times of the earth's rotation, is not contained in 'a moon,' or lunar month, so an exact number of moons, or even of days, is not contained in a year, or revolution of the seasons. Such observations as these led to methods of accommodating the one period to the other; or, in other words, to the

ADJUSTMENT OF THE CALENDAR.

The Chaldeans, Egyptians, and Indians, and indeed almost all the nations of antiquity, originally estimated the year, or the periodical return of summer and winter, by twelve lunations—a period equal to 354 days 8 hours 48 minutes 36 seconds. But the solar year is equal to 365 days 5 hours 48 minutes 49 seconds; or 10 days

21 hours 13 seconds longer than the lunar year, an excess named the *epact;* and, accordingly, the seasons were found rapidly to deviate from the particular months to which they at first corresponded; so that in thirty-four years, the summer months would have become the winter ones, had not this enormous aberration been corrected by the addition or intercalation of a few odd days at certain intervals. Thus was the calendar first adjusted, and the solar year estimated to consist of twelve months, comprehending 365 days. But no account was taken of the odd hours, until their accumulation forced them into notice; and a nearer approximation to the exact measurement of a year was made about forty-five years before the birth of Christ, when Julius Cæsar, being led by Sosigenes, an astronomer of his time, to believe the error to consist of exactly six hours in the year, ordained that these should be set aside, and accumulated for four years, when of course they would amount to a day of twenty-four hours, to be accordingly added to every fourth year. This was done by doubling or repeating the 24th of February; and, in order to commence aright, he ordained the first to be a 'year of confusion,' made up of fifteen months, so as to cover the ninety days which had been then lost. The 'Julian style' and the 'Julian era' were then commenced; and so practically useful and comparatively perfect was this mode of time-reckoning, that it prevailed generally amongst Christian nations, and remained undisturbed till the renewed accumulation of the remaining error of eleven minutes or so had amounted, in 1582 years after the birth of Christ, to ten complete days; the vernal equinox falling on the 11th instead of the 21st of March, as it did at the time of the Council of Nice, 325 years after the birth of Christ.

This shifting of days had caused great disturbances, by unfixing the times of the celebration of Easter, and hence of all the other movable feasts. And accordingly, Pope Gregory XIII., after deep study and calculation, ordained that ten days should be deducted from the year 1582, by calling what, according to the old calendar, would have been reckoned the 5th of October, the 15th of October 1582. In Spain, Portugal, and part of Italy, the pope was exactly obeyed. In France, the change took place in the same year, by calling the 10th the 20th of December. In the Low Countries, the change was from the 15th December to the 25th, but was resisted by the Protestant part of the community till the year 1700. The Catholic nations, in general, adopted the *style* ordained by their sovereign pontiff; but the Protestants were then too much inflamed against Catholicism in all its relations, to receive even a purely scientific improvement from such hands. The Lutherans of Germany, Switzerland, and, as already mentioned, of the Low Countries, at length gave way in 1700, when it had become necessary to omit *eleven* instead of ten days. A bill to this effect had been brought before the parliament of England in 1585, but does not appear to have gone beyond a second reading in the House of Lords. It was not till 1751, and after great inconvenience had been experienced for nearly two centuries, from the difference of the reckoning, that an act was passed (24 Geo. II., 1751) for equalising the style in Great Britain and Ireland with that used in other countries of Europe. It was enacted, in the first place, that eleven days should be omitted after the 2d of September 1752, so that the ensuing day should be the 14th; and, in order to counteract a certain minute overplus of time, that 'the years 1800, 1900, 2100, 2200, 2300, or any other hundredth year of our Lord which shall happen in time to come, except only every fourth hundredth year of our Lord, whereof the year 2000 shall be the first, shall not be considered as leap-years.' A similar change was about the same time made in Sweden and Tuscany; and Russia is now the only country which adheres to the *old style;* an adherence which renders it necessary, when a letter is thence addressed to a person in another country, that the date should be given thus:—April $\frac{1}{13}$ or $\frac{\text{June 26}}{\text{July 8}}$; for it will be observed, the year 1800, not being considered by us as a leap-year, has interjected another (or twelfth) day between old and new style.

The twelve calendar or civil months were so arranged by Julius Cæsar, while reforming the calendar, that the odd months—the first, third, fifth, and so on, should contain thirty-one days, and the even numbers thirty days, except in the case of February, which was to have thirty only in what has been improperly termed leap-year, while on other years it was assigned twenty-nine days only; a number which it retained till Augustus Cæsar deprived it of another day. The names of the twelve months are strictly Roman:—Thus, *January* is said to be derived from Janus, a divinity who presided over the commencement of all undertakings, whence his name was appropriately applied to the first month in the year; *February*, from *februo*, 'I purify,' because in that month funeral lustrations were performed at Rome; *March*, from Mars, the reputed father of Romulus; *April*, probably from *aperire*, 'to open,' in allusion to the opening or budding of vegetation; *May*, from Maia, the mother of Mercury, to whom sacrifices were offered on the first day; *June*, according to some, either from Junius, Juno, or Juniores; *July*, in honour of Julius Cæsar; *August*, in honour of Augustus; *September*, *October*, *November*, and *December*, signifying respectively seventh, eighth, ninth, and tenth, are the names which were employed when the Roman year consisted only of ten months, and began with March.

The commencement of the year, till a comparatively very recent period, was the subject of no general rule. The Athenians commenced it in June, the Macedonians in September, the Romans first in March, and afterwards in January, the Persians on 11th August, the Mexicans on 23d February, the Mohammedans in July, and astronomers at the vernal equinox. Amongst Christians, Christmas-day, the day of the Circumcision, the 1st of January, the day of the Conception, the 15th of March, and Easter-day, have all been used at various times, and by various nations, as the initial day of the year. Christmas-day was the ecclesiastical beginning of the year, till Pope Gregory XIII., on reforming the calendar, ordered it, in 1582, to begin thenceforward on the 1st of January. In France and England, the same practice commenced about the same time; but in the latter country, it was not till 1752 that legal writs and instruments ceased to consider the 25th of March as the beginning of the year. In Scotland, New-year's Day was altered, both for historical and legal purposes, from the 25th of March to the 1st of January, by a proclamation of King James VI., in the year 1600. The English plan was found exceedingly inconvenient; for when it was necessary to express a date between the 1st of January, which was the commencement of the historical year, and the 25th of March, which opened the legal one, error and confusion were sure to occur, unless it were given in the following awkward fashion:—January 30, 1648–9, or 164$\frac{8}{9}$. Even this was apt to lead to mistakes; and it is perhaps even to this day a matter of doubt with some intelligent persons, whether the execution of Charles I., of which the above is the usual appearance of the date, occurred in the year 1648 or 1649: it in reality occurred in the year which, by our present uniform mode of reckoning, would be called 1649.

The present mode of reckoning time has experienced no interruption in its leading features for many years, except under the French Republic. In September 1793, the French nation having resolved that the foundation of their new system of government should form their era, instead of the birth of Christ, whose religion they had in a great measure shaken off, resolved also that a calendar should be adopted on what was termed philosophical principles. The Convention, therefore, having

decreed, on the 24th November 1793, that the common era should be abolished in all civil affairs, and that the new French era should commence from the foundation of the Republic—namely, on the 22d September 1792, on the day of the true autumnal equinox—ordained that each year henceforth should begin at the midnight of the day on which the true autumnal equinox falls. This year they divided into twelve months of thirty days each, to which they gave descriptive names as follows:—From the 22d of September to the 21st of October was *Vendémiaire* (Vintage Month); to the 20th November was *Brumaire* (Foggy Month); to the 20th December was *Frimaire* (Sleety Month); this completed the autumn quarter: to the 19th January was *Nivose* (Snowy Month); to the 18th February was *Pluviose* (Rainy Month); to the 20th March was *Ventose* (Windy Month), which completed the winter quarter: to the 19th April was *Germinal* (Budding Month); to the 19th May was *Floréal* (Flowery Month); to the 18th June was *Prairial* (Pasture Month); here ended the spring quarter: to the 18th July was *Messidor* (Harvest Month); to the 17th August was *Fervidor* or *Thermidor* (Hot Month); to the 16th September was *Fructidor* (Fruit Month), which terminated the period of summer. In ordinary years there are five extra days—namely, from the 17th to the 21st of our September, inclusive: these the French called *Jours Complémentaires*, or *Sans-culottides*, and held as festivals; the first being dedicated to Virtue, the second to Genius, the third to Labour, the fourth to Opinion, and the fifth to Rewards. At the end of every four years, forming what they called a Franciade, occurred a leap-year, which gave a sixth complementary day, styled *Le Jour de la Révolution*, and employed in renewing the national oath to live free or die.

The *week*, though not exclusively a Christian or Jewish period of time, they also abjured. The thirty days of the month were divided into three parts, of ten days each, called *Décades;* of which the first nine—called Primidi, Duodi, Tridi, Quartidi, Quintidi, Sextidi, Septidi, Octidi, Nonidi—were working or common days, while the tenth, styled Décadi, was observed as a kind of Sabbath, though not exactly in the Jewish sense of the word. The French, however, in indicating any particular day, either by word or writing, generally mentioned only the number of the day of the month. The Republican Calendar was first used on the 26th of November 1793, and was discontinued on the 31st of December 1805, when the calendar used throughout the rest of Europe was resumed.

CYCLES.

A cycle, from a Greek word signifying *circle*, is a perpetual round or circulating period of time, on the completion of which, certain phenomena return in the same order; the end being thus, as it were, brought back to the beginning. Under such a definition, the common practice of accumulating years into centuries has of course no title to be classed: it is merely an arithmetical computation, like the equally common mode of counting by tens—forming, indeed, part of the same system.

The *Solar Cycle* is a period of twenty-eight years, during which the day of the month, in every succeeding year, falls on a different day of the week, from the first, till the cycle is completed; when the days of the month and week meet as at first, one cycle corresponding to another. By this cycle, which has no relation to the sun's course, we find 'the Dominical letters,' or those letters amongst the first seven in the alphabet—used to represent the days of the week—which point out the days of the month on which the Sundays fall during each year of the cycle. If there were 364 days in the year, the Sundays would happen every year on the same days of the month; if 365 exactly, every seventh year; but because the additional fractional period contained in the year makes an alteration of a day in every fourth year, the cycle extends to four times seven, or twenty-eight years.

The first solar cycle in the Christian era having begun nine years before the commencement of that era, to discover what year of the cycle the year 1856 forms, we must add 9, and divide the sum 1865 by 28, the period of the cycle, and the quotient 66 is the number of solar cycles that have passed during that era, the remaining 17 being the year of the cycle corresponding to 1856.

The *Lunar Cycle*—also called the 'Golden Number,' from its having been written in letters of gold by the Greeks, and the 'Metonic Cycle,' from its having been discovered by Meton, an Athenian astronomer—is a period of nineteen years, at the end of which the phases of the moon occur on the same days of the civil month as in a previous lunar cycle, and within an hour and a half of the same precise moment of time.

The first lunar cycle in the Christian era having begun one year before the commencement of that era, to discover what year of the cycle 1856 forms, we must add 1, and divide the sum 1857 by 19, the period of the cycle, and the quotient 97 is the number of lunar cycles that have passed during that era: the remainder, 14, shewing that 1856 is the fourteenth year of the next lunar cycle.

The *Dionysian Period* is a combination of the solar and lunar cycles, forming, by the multiplication of 28 by 19, a period of 532 years, at the expiration of which it is again new moon on the same days of the week and month as before: chronological events are compared and tested by such a calculation.

The *Indiction* may here also be noticed; though, were it not for severing it from the other cycles with which it is connected in the Julian period, it might perhaps more properly appear under the head of epochs and eras. This was a Roman period of fifteen years, the first of which commenced in the year 312 after the birth of Christ. It was appointed merely for the regulation of certain payments by the subjects of the empire; but it came to be observed by the Greek Church and the Venetian senate, as well as the court of Rome.

The *Julian Period* is a combination of the solar and lunar cycles with the Indiction; the respective periods of 28, 19, and 15 years being multiplied by each other, and the product, 7980 years, being what is called the Julian period, during which there cannot be two years having the same numbers for the three cycles; but at the termination of this period they return in the former order.

The year 1856 is the 6569th of the Julian period: hence it began about 700 years previous to the date vulgarly assigned to the creation of the world, and has been used instead of that era, to obviate the disputes of chronologers, and to reconcile their systems; for all agree as to the year in which the Julian period began.

The *Precession of the Equinoxes*, on the supposition that the motion on which it depends is uniform, is a cycle of 25,868 years, during which the points whereat the sun crosses the equator at the equinoxes retrograde along the whole circle of the ecliptic, and return to their former position. The present rate of this motion, which depends on the solar and lunar attraction of the quantity of matter heaped up along the region of the equator, is fifty seconds of a degree yearly, or a whole degree in seventy-six years. (See ASTRONOMY.)

Sir Isaac Newton endeavoured to fix the period of the Argonautic expedition by this cycle, and it has given rise to some curious and interesting speculations regarding the period when the signs of the zodiac were invented.

EPOCHS AND ERAS.

The principal difficulty which must have presented itself to nations desirous of preserving the memory of

events, as they might occur, in their annals from day to day, from month to month, and from year to year, and for long periods of years, would be to obtain a starting-point from which to number these days, months, years, and periods of years; and as no very marked astronomical event (unless, perhaps, eclipses) could render one of these starting-points preferable to another, such starting-points came practically and generally to consist, in early times, when nations had little mutual intercourse, of some event, important or known, perhaps, only to the nation dating from it. This event would form *an epoch*, so named from a Greek word signifying to stop. The enumeration and series of years computed from an epoch is called *an era;* and accordingly of epochs and eras there have been almost as many as there have been of nations. As the eras of ancient nations, however, have become obsolete, it would be useless, as it is here impossible, to enumerate all that we know of, or even any great number of them. But we shall notice a few of the most important in the meantime, reserving the names of all the other principal eras to be afterwards presented together in a tabular form.

The *Era of the Olympiads* is the first on record, and it also became the most celebrated of the ancient methods of computing lengthened periods of time. It took its rise amongst the Greeks 776 years before the birth of Christ. Public games had been instituted at Olympia, a city in Elis, which took place every fourth year, at the recurrence of the full moon after the summer solstice—namely, about the beginning of our July. As this festival made a great impression on the public mind, the people began to reckon by Olympiads, or recurrences of the Olympic games—an Olympiad comprising four years. The computation by Olympiads ceased after the 364th Olympiad, in the 440th year after the birth of Christ, as usually computed. The Greeks latterly adopted a new era, called

The *Era of Seleucus*, or the *Seleucidæ*, sometimes also called the era of Alexandria. This era commenced twelve years after the death of Alexander the Great, at the first conquest (312 B.C.), by Seleucus Nicator, of that part of the west which afterwards formed the immense empire of Syria. This era has also prevailed, and still exists, amongst the people inhabiting the Levant. The Jews reckoned by it till the fifteenth century of the Christian era, when they substituted the supposed era of the Creation, to be afterwards noticed; and they still begin their year according to it, in the months of September or October.

The *Roman Era* was reckoned by the Romans from the epoch of the foundation of their famous city Rome, an epoch taken to correspond to the 753d year before the birth of Christ. The computation of time by the Roman era ceased in the sixth century of the Christian era.

The *Christian Era*, of which we now live in the 1857th year, was not adopted as a mode of time-reckoning immediately after the commencement of Christianity. That religion existed long in a very obscure way; and the date of the birth of its founder did not, for several centuries, become a sufficiently important event in the eyes of enlightened nations to cause them to make it an era. The era of the Olympiads, the Roman era, the era of Seleucus, and the dates of ecclesiastical councils, and other events then considered of importance, were the common modes of reckoning, and continued partially to be so till a period less remote than many people suppose. Even in Italy, and its celebrated capital, Rome, which became the chief seat of Christianity at a very early period, this era was not used till the sixth century. It was introduced into France in the seventh, but not fully established till the eighth century. In Spain, though occasionally adopted in the eleventh, it was not uniformly used in public instruments till after the middle of the fourteenth century, nor in Portugal till about the year 1415. Now, however, all nations professing Christianity have abandoned other eras, and confined themselves to this; using the Latin words *Anno Domini*, 'the year of our Lord,' or their initial letters, A.D., to distinguish it; while for all dates previous to the generally received epoch of the era, the words *Anno ante Christum*, 'the year before Christ,' their abbreviation A.A.C., or more usually the letters B.C., signifying 'before Christ,' are used.

The *Era of the Hegira* commences at the epoch of the flight of Mohammed from Mecca to Medina, which took place on the 16th day of July 622 A.D. The Mohammedan year is regulated by this event; hence it is used by the Turks, Arabs, and other Mohammedans, comprising a large portion of the modern population of the world.

The *Mundane Era*, or era of the creation of the world, has been the subject of much controversy. As many as 300 different opinions, according to Kennedy, in his *Scriptural Chronology*, have been entertained regarding the period which elapsed between the creation and the incarnation. Some have made it 3616 years; others 6484. From the creation to the deluge, the computation of the Hebrew text makes a lapse of 1656 years; the Samaritan version only 1307; the Septuagint 2262. No ancient chronologist attempted to fix the epoch of the creation: some conceived it impious to do so. In modern times, the impiety has been supposed to lie all the other way. But some enlightened commentators have been bold enough to return to the ancient orthodox idea, so far at least as to maintain that the Scriptural epoch of the creation is indefinite, being merely cursorily alluded to in the words, 'In the beginning God created the heavens and the earth.' Geologists, in general, also adopt this wide interpretation. In the authorised version of the Bible, however, the chronology usually given places the epoch of the creation in the year 4004 B.C. Thus, 1 A.D. is 4004 A.M.; the letters A.M. being used as an abbreviation of *Anno Mundi*, 'year of the world.'

YEARS OF PRINCIPAL ERAS CORRESPONDENT TO 1856.

		Years.	Abbrev.
Era of Creation (Constantinopolitan account),		7364	A.M. Const.
Era of Creation (Alexandrian account),		7348	A.M. Alex.
" " (Jewish account), 23d Thebet,		5616	A.M.
Julian period,		6569	Jul. Per.
Caliyug (Hindoo),	Poos or Margaly,	4957	Cal.
Era of Abraham,	4th month of	3871	Ær. Abr.
Olympiads,	7th month 1st year of	662	Olymp.
Era of Rome,		2609	A.U.C.
Era of Nabonassar,	8th month of	2604	Ær. Nab.
Egyptian era,	25th Cohiac,	2602	A. Æg.
Era of Death of Alexander,	3d month,	2179	A. Mort. Alex.
Spanish, or era of the Cæsars,		1894	A. Cæs.
Dioclesian, or era of Martyrs,	25th Cohiac,	1572	Ær. Diocl.
Hegira,	22d Rabiu II.	1272	A.H.
Chinese year,	53d year of 71st cycle of 60 years.		

MISCELLANEOUS PERIODS.

Besides these major periods, we have others of less significance, but still useful to be known, as they are frequently alluded to in works of a historical nature. Thus, a *lustre* (Lat. *lustrum*) is a period of five years; or, more properly, the completion of fifty months, at the end of which term a census was taken of the Roman population. A *generation* is the interval of time elapsed between the birth of a father and the birth of his son, and is generally used in computing considerable periods of time both in sacred and profane history. The interval of a generation is consequently of uncertain length, and depends on the standard of human life, and whether the generations are reckoned by eldest, middle, or youngest sons. Thirty years are usually allowed as the mean length of a generation, or three generations for every hundred years. A *reign* is the interval that elapses between the accession and demise of a monarch or supreme governor, and is a

term in frequent use by historians. It is a period, however, of very uncertain duration, and differs in different countries, according as the sovereign may be liable to assassination, deposition, and the like. Dr Hales has, however, shewn that the average standard of reigns is about twenty-three years, reckoning from a series of 454 kings in 10,105 years. A *century* (*centum*, a hundred) is a period of one hundred years, reckoning from the commencement of the first year in any given century; thus the current century is the nineteenth of the Christian era.

TABULAR CHRONOLOGY.

Under this head the leading events, phenomena, or facts recorded in history, are arranged in the order of time in which they have occurred—that is, in chronological order. When we look back, however, over the lapse of 3000 or 4000 years, and consider the imperfect modes of record, the changes and transcriptions through which these records have passed—or even the absence of all record, save undated monuments and vague tradition—it will not be surprising that the tabular arrangements of chronologists should be so frequently inaccurate and contradictory. A perfect tabular chronology is what mankind can now never hope to attain; a full record—even reckoning only such events as are of medium general interest—would be too vast either for compilation or perusal. All that we can reasonably hope to attain, is an approximation to the leading facts in the early history of our race, and a brief indication of the more important occurrences in later times. Referring the reader to the systematic chronologies of Newton, Blair, Playfair, Sir Harris Nicolas, and others, we shall merely remark, that the best mode of tabulating events is that which exhibits the dates in bold characters, and endeavours to arrange in juxtaposition the leading occurrences in the principal countries of the world. By these means, reference is greatly facilitated, and a notion of civil progress more intelligibly conveyed. Particular chronologies, as of meteorology, agriculture, ecclesiastical history, and the like, are most advantageously constructed in separate tables; that is, by tabulating, in consecutive order, the leading incidents in the progress of the individual science or subject. The language of tabular chronology should always be concise, elliptical rather than expletive—a mere indication rather than an account of the event recorded.

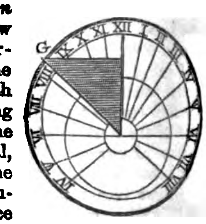
HOROLOGY.

Reference has already been made to the heavenly bodies and their motions as the most primitive and natural, as well as most perfect time-keepers. Our attention here, therefore, must be confined to those artificial machines which have been invented chiefly for the purpose of adding to the convenience of these, by dividing the unit of astronomical time-keeping—namely, the day—into fractional parts, such as hours, minutes, and seconds; there being no such convenient and desirable measurement obvious in nature. The science which explains the methods of so measuring and marking the fractional parts of the day is termed *horology*, from two Greek words, signifying *hour* and *discourse*—a term comprehensive of every time-keeping contrivance, from the simplest sand-glass to the most perfect chronometer. The instruments to which we shall here advert are dials, depending upon the shifting shadow of an object illuminated by the sun; clepsydræ, depending upon the equable flow of a liquid; and clocks and watches,* whose movements are determined by weights and springs.

* Although modern machines for measuring time are designated by the general appellation of clocks and watches, they are also distinguished by peculiar names arising from certain modifications in their construction, or from certain particular purposes they are intended to serve. By the term *clock* is understood an instrument which not only shews, but also strikes the hours; a *time-piece* is one which shews the hours without striking them; a *quarter-clock* is one which strikes the quarters as well as the hours; an *astronomical clock* is one which shews sidereal time; a *watch* is a portable or pocket time-piece; a *repeater* is one having a contrivance, by means of which it can be made to repeat the hours; a *chronometer* is a watch of the best kind, or one fit to be employed for astronomical purposes.—*Brande's Dictionary of Science.*

SUN-DIALS.

Long before the invention of any artificial time-keeper, the interval between sunrise and sunset was really divided, with no little accuracy, even amongst the rudest nations, simply by the shortening, turning, and lengthening of the shadows of trees, rocks, and mountains; and it was this primitive mode of dividing the day which no doubt naturally suggested the first idea of sun-dials. The earliest time-measurer of this description of which we have any historical notice, is the dial of King Ahaz, who lived about 742 years before the birth of Christ. According to Herodotus, the Greeks learned the use of them from the Chaldeans, probably through the Babylonian priest and astronomer Berosus, who taught and expounded in Athens about 540 years before Christ. Mention is made of the hemisphere or dial of this philosopher; and the octagonal Temple of the Winds, which is still standing, shews on each side the lines of a vertical dial, and the centres where the gnomons were placed. In Rome, sun-dials were not known till 293 B.C., when one was erected near the Temple of Quirinus—the rising and setting of the great luminary being the only standards of reckoning previous to this period. The Romans at this time were not aware that a dial made for Rome is not suited to other places. The ancients used hemispherical dial-plates, and placed the radius, which throws the shade, in the direction of the north polar star. Subsequently, vertical plane dials came to be the usual form, as may be seen on the fronts and gables of many of our old mansions. At present, the most common construction is the horizontal dial, or that in which the plane of the dial-plate is parallel to the horizon. In this form the style or *gnomon* G, the edge of the shadow of which determines the hour-line, runs in the plane of the meridian—that is, due north and south; while its sloping edge forms an angle with the horizon, or plane of the dial, equal to the latitude of the place in which the instrument is situated, and hence parallel to the earth's axis.



Although a sun-dial may certainly be adjusted so as to point out the time of day within a few minutes, it is needless here to dwell further on the details of an instrument now of little use. The most perfect of sun-dials being only available in sunshine, and not at all through the night—in which, by the way, moon-dials were sometimes used—they were partly superseded, even at a very remote period, by

CLEPSYDRÆ AND SAND-GLASSES.

It has been thought that the regular motion of the dropping of water, and the simpler forms of clepsydræ, or water-clocks, were used for the measurement of time even previous to the invention of sun-dials. They certainly were known in very remote antiquity, and were then used in various parts of Asia and Europe; in China, India, Chaldea, Egypt, Italy, and Greece; into the last of which countries they were introduced by Plato. Julius Cæsar found them even in Britain. It was by

them that he discovered some of the nights to be shorter or longer in this country than in Italy, which is nearer the equator, or line of equal days and nights. The Romans themselves had clepsydræ 100 years before Cæsar's invasion; and it is supposed that the Phœnicians had introduced them into Britain through Cornwall, where they traded for tin. The clepsydra, invented by Ctesibius of Alexandria, 145 B.C., consisted of a jar containing water, which slowly escaped by a hole at the bottom, while the oar of a miniature boat on the surface, as it sank with the fall of the water, pointed out the hours, which were marked on the side of the jar. It is even alleged that toothed-wheels were applied to clepsydræ by Ctesibius. Such instruments, however, though brought to great perfection in the ninth and tenth centuries, and indeed still used in India, have never been made to measure time with great accuracy. The principal defect is the unequal dropping of the water, caused by the varying depth or weight of the liquid in the containing vessel, increase or decrease of temperature, and change of barometric pressure. Very ingenious attempts have been made to remedy this defect, but the greater complexity and delicacy thereby occasioned, render the instruments of very little practical value. As time-keepers, clepsydræ may therefore be considered as superseded by ordinary clocks and watches.

The running of fine well-dried sand through a tube, or from an orifice in a containing vessel, was another obvious species of regular motion, very analogous to the flowing or dropping of water. Accordingly, sand-glasses, still in use in this and other countries, were of very early invention. We have evidence of their employment in the East about a couple of centuries before the Christian era. Though now used only for rude and trivial purposes—the half-minute glass being still employed on ship-board, and the two and a half or three minute egg-glass by the housemaid—some centuries ago, in Western Europe, they were the almost universal measurers of brief intervals; and hence the numerous allusions of our poets, and the symbolical representations on our monuments and sculptures.

PLANETARIUMS OR ORRERIES.

It is rather a curious circumstance, that, long before the invention of clocks or watches, artificial machines were constructed, imitative of the motions of the sun, moon, and planets—the natural time-keepers.

Of the planetariums of modern times, the first in England was one made for Lord Orrery, whose name has since been given to such machines. The talented and self-taught astronomer, Ferguson, who was originally a poor Scottish herd-boy, made several orreries, and used chronometers to keep them in motion. But though the accuracy with which wheels and pinions can be made to represent different revolutions is beautifully illustrated by the best of these machines, they can give no just conception of the relative size, distance, or velocity of the planets, or hence of the periods of their revolution. 'As to getting correct notions on this subject (the magnitude and distances of the planets),' says Sir John Herschel, 'by drawing circles on paper, or, still worse, from those very childish toys called orreries, it is out of the question.' A verdict so decided, and from such a source, renders any attempt at description or illustration unmeaning and superfluous.

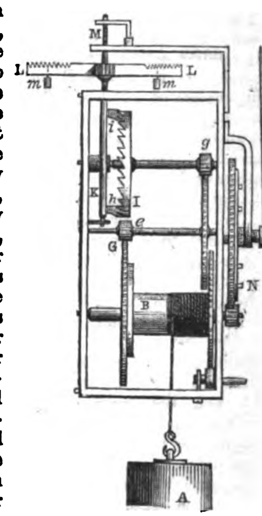
CLOCKS.

The strong hold which the planetary motions appear to have taken on the minds of our forefathers, as the great antitypes of all true time-keepers, is also curiously manifested in the fact, that even when a more detailed measurement of time became necessary, in the intellectual progress of nations, these motions still continued to be represented, so that the very first clock of which we have any perfectly authentic account—that, namely, invented by Wallingford, abbot of St Albans, in 1326—not only shewed the hours, but the apparent motion of the sun, the changes of the moon, the ebb and flow of the tides, &c. This, however, was by no means the first clock ever constructed; instruments with weights, wheels, pinions, and a balance, for the measurement of time, having been long previously known, though by whom invented, appears to be a subject of much controversy. Doubtless, they required more than the intellect of a single mind. Be this as it may, the most ancient clock of which we have any description is that of Henry Vic or De Wyck, a German, erected in the tower of the palace of Charles V., king of France, in 1379; and rude and imperfect as it was, the analogy of modern invention, especially in watches, would lead us to think that it must have been the fruit of several centuries of thought and improvement.

A portrait of this parent of modern time-keepers may be interesting to our readers; and, from its comparative simplicity, will be well adapted as a groundwork for further explanation of the mechanism of clocks and watches in their more complex and intricate forms. It will, moreover, shew the general mode of construction adopted in the fourteenth century, including the balance with weights, by which the motion was then regulated, instead of as now by a pendulum.

General Movement and Regulation of Clock-work.

Without requiring to enter into any very minute detail of the manner in which motion in a clock or watch is successively communicated from one toothed-wheel G or I, or pinion *e* or *g*, to another, which, indeed, would in some instances only tend to perplex the mind of the general reader, it will be readily understood that the weight A below the clock-work, wound up by a cord on the cylinder B, in its constant tendency to fall to the ground, will cause the cylinder to turn round on its axis as it falls, and as the cord uncoils; and thus one toothed wheel or pinion will set another in motion, till the movement be communicated to the crown-wheel, escapement-wheel, or wheel of rencounter (I), the teeth of which so act on the two small levers or pallets (*i*, *h*) projecting from, and forming part of, the suspended upright spindle or vertical axis (KM), on which is fixed the regulator or balance (LL), that an alternating or vibratory instead of a circular motion of the balance itself will be the result. The rotatory motion of the wheel-work, in short, will be converted into a vibratory motion by the alternate catching of the levers by the teeth of the crown or escapement wheel, and their alternate escape from them.



De Wyck's Clock.

Now, it will at once appear manifest that a heavy weight, such as that here represented, operating on a few wheels thus arranged, unless it have some counteractive weight, or other check, to modify and balance its operation, will rapidly run down even to the ground, if the height of the clock-work and the length of the cord attached to the cylinder permit it, causing the wheels to rotate, the balance to vibrate, and the hands to revolve

on the face of the clock, with similar rapidity, increasing every moment, till the weight be fairly run down. It is this rapid motion of the wheel-work which begins in a *modern* clock whenever the *pendulum* is taken away, while the weights are still attached to the cylinders; and the rapid ticking then heard is the uncounteracted operation of the crown-wheel, moved by the falling weight upon a piece of mechanism similar in purpose to the levers and spindle in the above figure. To prevent this rapid unwinding of the clock-work, then, and to adjust it to the more deliberate measurement of time, we have, in De Wyck's clock, the balance, *loaded with two weights* (*m*, *m*); and the further these are removed from the axis or spindle (KM), the more heavily will they resist and counteract the escapement of the levers and the rapidity of the rotation of the escapement-wheel, till the clock be brought to go neither too quick nor too slow.

Pendulum and Escapement.

What the balance and the weights attached to it in De Wyck's clock were to clocks of an ancient date, the pendulum is, in general, to modern clocks; the oscillations of the pendulum, and the vibrations of the balance, being completely analogous in purpose and effect, both being kept up or sustained by the 'escapement,' while both require, or, as it were, demand, by the law of gravity, a certain time for their performance; and thus, by reaction, check and equalise the exercise of those very powers and movements by which they are kept in play. The measurement of time being thus regulated by the oscillations of the balance or the pendulum, this part of the mechanism of a clock, including the escapement, is of primary interest and importance; and we shall find this also to be the case in the numerous contrivances, chiefly by English artists, to effect the same object to the best advantage in the still more delicate and ingenious mechanism of watches. We may here also remark, that so invaluable is the principle of *regulation*, whether by oscillation or rotation, and so generally and extensively useful in other respects, that from the smoke-jack to the steam-engine it has, in one form or other, been called into practical operation.

Galileo, the great astronomer, when a student at Pisa, happened to discover while engaged in the cathedral there—not in meditating on the imposing ceremonial of the Catholic Church, which was then in progress, but in what, to many a good Catholic, would undoubtedly have seemed the vacant, idle, and profane contemplation of the lamps which swung from the roof—that the oscillations of a pendulum, whether great or small, are performed in equal times in each pendulum—an important fact, the truth of which he tested, not by the beats of his watch (for no such instrument then existed), but by the beats of a natural time-keeper to which we have not yet alluded—namely, the pulse. He afterwards discovered what was ultimately demonstrated by Newton—that 'the shorter the pendulum, the less is the time of its vibration;' or, in other words, that the number of oscillations performed by a pendulum in a given time depends on its length—four times the length producing twice the number of oscillations. A pendulum, the length of which, from the point of suspension to the centre of the weight attached to its lower extremity, is 39 inches 2 tenths, will oscillate once precisely every second in the latitude of London; not in any other latitude, however, as has been found by experience; the number of oscillations with the same length of pendulum diminishing towards the equator, where oscillations equal in length to 2 minutes 15 seconds a day will be lost; while, on the other hand, they will increase towards the poles, where a proportional number of oscillations will be gained. Thus, as already explained under the LAWS OF MATTER, the pendulum of a clock, made and adjusted to time in London, requires to be lengthened if taken nearer to the poles, or shortened if taken towards the equator. The greatest possible nicety, indeed, is required in the adjustment of the length; for a difference, if in extent amounting to the 1000th part of an inch, would cause an error of about one second a day; therefore to make a pendulum go slower by one second a day, it must be lengthened by the 1000th part of an inch; and to make it go quicker, it must be shortened in the same proportion. The following are the results of some measurements of the seconds' pendulum at different latitudes in the northern hemisphere :—

Spitzbergen,	79°	49′	58″	N. Lat., . .	39·2146 inches.
Edinburgh,	55	58	40	" , .	39·1554 "
London,	51	31	08	" , . .	39·1390 "
Jamaica,	17	56	07	" , .	39·0350 "
Sierra Leone,	8	29	28	" , . .	39·0195 "

The first use which Galileo, then a medical student, made of his valuable discovery, was to ascertain the rate and variations of the pulse; and its application to clock-work was an after-thought. It is even denied that he did more than suggest such an application; or, as has been also alleged, that at all events his son put his suggestion into execution; and accordingly the merit of the invention of pendulum-clocks is very generally attributed to Hüygens, a learned Dutchman, about 1657. This celebrated philosopher, in adapting the pendulum to the mechanism previously invented, had little more to do than simply to add a new wheel to the movement, so as to enable him to place the crown-wheel and spindle in a horizontal instead of a perpendicular position, that the lower arm of the balance—then of course perpendicular, instead of horizontal, as in De Wyck's clock—might be extended, as it were, downwards, and thus, in fact, be converted into a pendulum. The principle thus adopted, however, from the peculiar action of the levers and spindle, required a light pendulum and great arcs of oscillation; and the consequence was, as has been remarked, that 'Hüygens's clock governed the pendulum, whereas the pendulum ought to govern the clock.' About ten years afterwards, the celebrated Dr Hooke invented a better method, which was introduced by Clement, a London clockmaker, in 1680, and enabled a less maintaining power to carry a heavier pendulum, which also making smaller swings or arcs, was less resisted by the air, and therefore performed its motion with greater regularity. This was called the *anchor escapement*, and it is still in use, together with the practice to which it gave rise of suspending the pendulum by a thin flexible spring instead of a cord, which was liable to change its length by moisture; an evil, however, perhaps fully equalled by the variation of the elasticity of the spring by heat and cold. The seconds' pendulum, with the anchor escapement, was called the *royal* pendulum. As this plan, however, was found to cause a reaction or retrograde movement of the wheels, and has hence been called the *recoil* escapement, a further improvement was made about the beginning of the eighteenth century by George Graham, another English artist, who invented the repose or *dead* escapement.

The wheels are kept by this escapement in a state of repose or rest during the whole oscillation of the pendulum, except at the moment when it receives its impulse from the crown-wheel. Requiring smaller arcs, too, even than before, the oscillations are made in more equal times. A still more perfect modification of the escapement is the free or *detached*, but it is more difficult to execute. The *half-dead* escapement, also, has been introduced as a mean between the dead escapement—an increase of power with which causes a clock to lose time

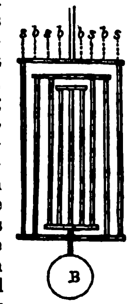
—and the recoil escapement, with which a similar increase of power causes one to gain. For the purposes of ordinary clocks, this mode of escapement has been found to answer very well.

In the great clock constructing for the new Houses of Parliament at Westminster, the pendulum is upwards of thirteen feet long, to beat two seconds, and its bob weighs six hundredweights. For keeping up the movement, a new contrivance, called the *gravity escapement*, is applied. It is thus described: 'The attempt has been made to give the push by the agency of a power that is, on account of its own intrinsic nature, absolutely unvarying. On each side of the pendulum-rod, a sort of small metallic hammer is hung upon a peg. The swinging of the pendulum first draws out a little bolt, that stopped the turning of a wheel; the wheel then goes round, under the influence of the weight, lifting one of the little hammers, as it does so, until it is caught by another bolt. The hammer-head next falls by its own gravity, and strikes the pendulum-rod just as it is in the act of descending, communicating the force of its blow to quicken the movement; the same thing is afterwards repeated on the opposite side of the vibration, and then again on the same side; so going on alternately. But the blow that is given to the pendulum depends upon nothing but the force of the hammer, which is lifted up by the train of wheel-work, and then descends with a strength that is exactly proportioned to its weight; but as this weight does not vary by the fraction of a grain, the blow never alters; its push is unchanging, and always the same in amount. The wheel has three stops and cogs on it, and goes once round in three beats of the pendulum, or in six seconds. . . . . This beautiful contrivance—now technically known as the gravity escapement—is of the highest importance in the practical applications of the science of horology; for it is found that when it is employed, all the teeth of the several wheels may be rough, just as turned out from the casting, and the clock will nevertheless keep better time than it would have done with the most perfectly finished teeth under other arrangements.'

Compensation Pendulums.

Pendulum-rods, which are usually made of metal, though sometimes of wood, especially in church-clocks, were next found to vary in length by variations of temperature, according to that law of nature by which every body increases in volume or in actual size by heat, and diminishes or contracts by cold. The inevitable consequence of the influence of such variations on the length of the pendulum will at once be seen, from what has been already said, to be an increase of the number of its oscillations in a given time while in cold temperatures, and hence shorter than its mean length, as in winter, or even at night, or in cold situations; and a diminution of them while in warm temperatures, and hence longer, as in summer, or even during the day, or in warm situations: and a pendulum with a metal rod will cause a clock to vary several seconds in a day from such changes alone. To insure, therefore, a still greater accuracy and uniformity in the measurement of time than had previously been obtained, various ingenious but simple devices have been put into practice, wherein the very cause of the inaccuracy has been made subservient to the end desired. And here the talent of the artist Graham again displayed itself, and led the way to every other modification of the primitive *idea*, however dissimilar in detail, and whether applicable to pendulums or balances, to clocks or watches. Indeed, the first method of 'compensation' adopted for pendulums has, with some little improvement, ultimately superseded all its more recent modifications. This method Graham called the *mercurial compensation*, and it consists simply of a tube or cylindrical glass-jar containing quicksilver or mercury, and attached to the lower end of a steel-rod in the arc of its oscillation. As the steel-rod lengthens by heat, the mercury expands in volume, and rises in the tube; while, as the rod shortens by cold, it contracts, and sinks or falls. Thus the centre of oscillation remains ever at the same distance from the point of suspension, or upper extremity of the pendulum; or, in other words, the pendulum, in fact, remains ever of the same length.

Graham also conceived the notion of another compound pendulum, composed of different metals, so arranged as to compensate each other by their *difference* of expansion or contraction. This modification of the idea of a compensating pendulum was more fully developed by John Harrison, another celebrated artist, who in 1726 invented the gridiron pendulum, composed of five rods of steel and four of brass, so arranged that the rods which expand the most raise the weight or bob as much as the rods which expand the least depress it. In the annexed fig., the bars marked *s* are of steel, those marked *b* are of brass; the centre rod of steel is fixed at the top to the cross-bar connecting the two middle brass-rods, but slides freely through the two lower bars, and bears the bob B. The remaining rods are fastened to the cross-pieces at both ends, and the uppermost cross-piece is attached to the axis of suspension. It is easy to see that the expansion of the steel-rods tends to lengthen the pendulum, while that of the brass-rods tends to shorten it; consequently, if the two expansions exactly counteract each other, the length of the pendulum will remain unchanged. The relative lengths of the brass and steel bars are determined by the expansions of the two metals, which are found by experiment to be, in general, nearly as 100 to 61. If, then, the lengths of all the five steel-bars added together be 100 inches, the sum of the lengths of the four brass-bars ought to be 61 inches. When the compensation is found, on trial, not to be perfect, an adjustment is made by shifting one or more of the cross-pieces higher on the bars. This pendulum has been greatly improved by Troughton, who substituted for the two pair of brass-rods two cylinders of brass, sliding the one within the other, to which the steel-rods are attached.



Unfortunately, however, this compensation changes, as all metals do, not continuously and gradually, under the influence of heat or cold, but by jerks. The mercurial pendulum, therefore, under certain improvements by Thomas Reid, a talented Edinburgh artist, and by others, has of late been frequently resumed; and it has been found that time-keepers provided with this pendulum and a dead escapement do not vary, on the average, more than a quarter of a second daily—a degree of accuracy wonderful, indeed, when contrasted with the fact that down to the middle of the sixteenth century clocks were incapable of going nearer to accurate time than about 40 minutes within the twenty-four hours, and were nevertheless held to be precision itself compared with all other methods of measuring time then known.*

* Before quitting the subject of pendulums, it is worthy of remark, that their mutual action or sympathy while oscillating near each other on the same wall, so long as they are mutually connected by a rail or shelf common to both, or so long as the cases of the clocks to which they belong are either fixed to each other, or standing on the same flooring plank, is a very singular phenomenon, observed by Hüygens, Ellicot, De Luc, Reid, and many other artists. One pendulum will even stop another, it is said, in such circumstances, and will again cause it to resume its vibrations till it stop, alternately, itself. It has also been found that two clocks with pendulums of nearly equal length and power, or weight, though differing in their measurement of time while apart, will so vibrate in unison when thus connected, as to keep time together with the most surprising accuracy, till they are again separated, or till the plank connecting them be sawn asunder. This singular but not altogether unaccountable influence appears to be not unlike that sympathy of sound between

Other Improvements.

While improvements were effecting in the escapement and pendulum of clocks, the ingenuity of artists was not confined to these alone. Till the beginning of the sixteenth century, clocks were of great bulk, and only fit for turrets or large buildings; and although after this period they were made small enough to be introduced into apartments, there could be no such thing as a really portable clock, far less a watch, till weights and pendulums were got rid of altogether. The substitution of a mainspring for a weight, therefore, constituted a great era in horology, or the science of time-keeping; and this took place about the middle of the sixteenth century, and was shortly afterwards followed by the invention of the *fusee*, a very necessary appendage to the mainspring. But as these inventions completely altered the form and principles of horological machines, and together with that of the spiral escapement-spring, and other improvements, which soon followed that of the pendulum, rather constitute peculiar features of the watch than of the clock—although they were mostly applied at first only to portable time-pieces of the nature of clocks, in which they are indeed still used—we shall reserve the explanation of these ingenious pieces of mechanism till we come to treat of watches. Meantime, there is another part of the works which requires to be here noticed—namely, the

Mechanism for Striking the Hours.

It is not known when the alarm or when the striking-mechanism of the clock was first applied. The alarm was adopted for the use of the Romish priesthood, to arouse them to their morning devotions. The first striking-clock probably announced the hour by a single blow, as they still do, to avoid noise, in most, if not all, of the Scottish churches. In De Wyck's clock, the wheel N, with its projecting pins, served to discharge the striking part, which it has not been thought necessary to illustrate. Like other old clocks, it looked against an interrupted hoop, fixed on what was called the *hoop-wheel;* and the eleven notches on the edge of the plate-wheel determined the hours, or particular number of blows which the hammer should give. During the seventeenth century there existed a great taste for striking-clocks, and hence a great variety of them. Several of Tompion's clocks not only struck the quarters on eight bells, but also the hour after each quarter; at twelve o'clock, 44 blows were struck; and between twelve and one, no less than 118! Many struck the hour twice, like that of St Clement Danes, in the Strand, London, first on a large bell, and then on a small one. Others, again, were invented so as to tell the hours with the least possible noise; also by the aid of two bells, each blow on the small one indicating five hours.

The striking part of a clock is rather a peculiar and intricate piece of mechanism. In ordinary clocks, the impelling power is a weight similar to that which moves the time-measuring mechanism itself; but the pressure of this weight on the striking-machinery is only permitted to come into play at stated periods in course of the workings of the time-keeping apparatus—namely, at the completion of every hour; when the minute-wheel, which revolves once in an hour, and carries the minute-hand of the clock along with it, brings it into action by the temporary release of a catch or detent, permitting the weight wound up on the cylinder of the striking-apparatus to run down for a little, in doing which, the hammer is forced into action, so as to strike the bell. Whether the strokes shall be one or many, is determined principally by two pieces of mechanism, one called a *snail*, from its form or outline, with twelve steps, and the other a *rack*, with twelve teeth; but the intricate action of the whole it would be in vain here to attempt to explain. Suffice it to say, that the time during which the striking-weight is *allowed* to descend, varies according to the turning of the twelve steps of the snail on its axis, and the position of the twelve teeth of the rack, at different hours of the day; being sometimes only long enough to permit one blow to be given by the hammer on the bell, and at another time long enough for twelve such blows.

The lifting piece of the rack-hook, in some clocks, may be raised by pulling a string attached to a small additional piece of mechanism, and thus the clock is made to repeat the hour last struck at any time required—an addition useful through the night, or to the blind. The modes, however, by which clocks as well as watches have been made repeaters, have been very various. Repeating-clocks were first invented by Barlow, an English clergyman, and executed by Tompion in 1676. Some have been made to repeat both hours and quarters at any time, and to indicate the time by blows which might be felt but not heard.

The bells connected with clocks, especially those of churches and other public buildings, are often worthy of notice, either on account of their gigantic size, or on account of the arrangements by which they are made to perform a variety of musical chimes. The largest bell in the world is the 'Monarch' of Moscow, which is above 21 feet in diameter and in height, and weighs 198 tons. It was cast in 1734, but fell down during a fire in 1737—was injured, and remained sunk in the earth till 1837, when it was raised, and now forms the dome of a chapel, made by excavating the space below it. Another bell in Moscow weighs 80 tons. The great bell of Peking, 13 feet in diameter, and 14 feet high, weighs 53½ tons; those of Olmütz, Rouen, and Vienna weigh nearly 18 tons. The most noted bells in Britain are—'Great Peter,' placed in York Minster in 1845, whose weight is nearly 11 tons; 'Great Tom' of Lincoln, 5½ tons; and the great bell of St Paul's, 5 tons. The bell which is to strike the hours in the new Palace of Westminster is to be 8 feet high and 9 feet wide, and will weigh 15 tons; the hammer is to weigh four hundredweights. The metal of which bells are made is generally an alloy of 80 parts copper and 20 tin. An English *bell-metal*, analysed by Dr Thomson, yielded 800 copper, 101 tin, 56 zinc, and 43 lead.

The illumination of clocks was a favourite idea in the seventeenth and eighteenth centuries, and is equally useful in a public way as the striking of hours or the ringing of bells. It was only during the current century, however, that any plan was adopted for public clocks; the first notion being to light them from without, by reflecting the light of a common lamp or gas-jet on their dials. This simple method is still employed, but is vastly inferior to the employment of a translucent dial, with a strongly reflected light from behind. Recently, the pure brilliancy of the Bude-light has greatly contributed to the improvement of this very useful practice.

Curious Clocks.

Various and ingenious, as well as often highly curious, have been the forms and purposes displayed in the construction of clocks, even from their earlier epochs down to the present day. We have already instanced some of an ancient date which pointed out the motions of the sun and moon, the ebb and flow of the tides, &c. Others of a more fanciful description followed. The famous astronomical clock of Strasburg, completed by Isaac

two musical instruments tuned in unison, wherein, when a chord of one is struck, the other, placed in a proper situation, though untouched, responds or echoes back the sounds at first called forth. And as in the combinations of certain medical substances, or in various other combinations, the general result of all the elements is obtained as a steady mean to be depended on, without the special failure, fault, or disadvantage of any one element in the combination, accuracy of time-keeping, of a remarkable kind, might readily be obtained by this singular mode of bringing out, by a combination of pendulum-clocks, an average rate of motion.

Habrecht about the end of the sixteenth century, deserves a prominent place in our catalogue. It has been recently renovated by a M. Schwitgue, after four years' labour; but its original movements are thus described in Morrison's *Itinerary:* 'Before the clock stands a globe on the ground, shewing the motions of the heavens, stars, and planets. The heavens are carried about by the first mover in twenty-four hours. Saturn, by his proper motion, is carried about in thirty years; Jupiter, in twelve; Mars, in two; the Sun, Mercury, and Venus, in one year; and the Moon in one month. In the clock itself there are two tables on the right and left hand, shewing the eclipses of the sun and moon from the year 1573 to the year 1624. The third table, in the middle, is divided into three parts. In the first part, the statues of Apollo and Diana shew the course of the year, and the day thereof, being carried about in one year; the second part shews the year of our Lord, and the equinoctial days, the hours of each day, the minutes of each hour, Easter-day, and all other feasts, and the Dominical letter; and the third part hath the geographical description of all Germany, and particularly of Strasburg, and the names of the inventor and all the workmen. In the middle frame of the clock is an astrolabe, shewing the sign in which each planet is every day; and there are the statues of the seven planets upon a circular plate of iron; so that every day the planet that rules the day comes forth, the rest being hid within the frames, till they come out, of course, at their day—as the sun upon Sunday; and so for all the week. There is also a terrestrial globe, which shews the quarter, the half-hour, and the minutes. There is also the figure of a human skull, and the statues of two boys, whereof one turns the hour-glass, when the clock hath struck, and the other puts forth the rod in his hand at each stroke of the clock. Moreover, there are the statues of Spring, Summer, Autumn, and Winter, and many observations of the moon. In the upper part of the clock are four old men's statues, which strike the quarters of the hour. The statue of Death comes out at each quarter to strike, but is driven back by the statue of Christ, with a spear in his hand, for three quarters; but in the fourth quarter that of Christ goes back, and that of Death strikes the hour with a bone in his hand, and then the chimes sound. On the top of the clock is an image of a cock, which twice in the day crows aloud, and claps his wings. Besides, this clock is decked with many rare pictures; and being on the inside of the church, carries another frame to the outside of the walls, whereon the hours of the sun, the courses of the moon, the length of the day, and such other things, are set out with great art.'

Other ancient clocks displayed processions of saints, with obeisance to the Virgin and Child, &c.; and scarcely a town of any importance was without some curiosity of this sort peculiar to itself. Many curious specimens were invented in the seventeenth century; amongst which were a variety measuring time, or at least moved, by balls running down inclined planes, swallowed up by, and traversing the bodies of, brazen serpents, or descending in metallic grooves, to be again thrown up by Archimedean screws: some were made to go by their own weight, descending inclined planes, and thus avoiding the casualties to which mainsprings and weight-lines are liable; others, by means of springs, were even made to ascend such planes. One clock was simply and ingeniously hung like a lamp from the ceiling, and was kept going by its own descent, the winding up consisting merely of pushing it again towards the ceiling. In another, the dial formed the brim of a plate, filled with water, in which swam a tortoise, turning marvellously with the hour, and ever pointing towards it—by magnetic attraction, as every one would now readily conceive; and this favourite idea was varied by many other simple contrivances. Within the last few years, not a little wonder of a similar kind, we recollect, was excited by a puzzle-clock, with an hour-hand proceeding from the centre of a crystal dial-plate, perfectly transparent, and moving without any visible connection with mechanism. In this case, a piece of glass itself, rotating in the interior of the dial, constituted the requisite mechanism.

More interesting, perhaps, than any of these, and yet of the simplest construction, and of the most common material, are the *electric*, or rather *electro-magnetic clocks*, invented by Mr Bain, formerly of Edinburgh. The prime mover of these machines is the electric currents of the earth, brought to bear upon the machinery, as thus described by a gentleman for whom one of the earliest was constructed. 'On the 28th of August 1844, Mr Bain set up a small clock in my drawing-room, the pendulum of which is in the hall, and both instruments in a voltaic circle as follows:—On the north-east side of my house, two zinc-plates, a foot square, are sunk in a hole, and suspended by a wire, which is passed through the house to the pendulum first, and then to the clock. On the south side of the house, at a distance of about forty yards, a hole was dug four feet deep, and two sacks of common coke buried in it; among the coke another wire was secured, and passed in at the drawing-room window, and joined to the former wire at the clock. The ball of the pendulum weighs nine pounds; but it was moved energetically, and has ever since continued to do so with the self-same energy. The time is to perfection; and the cost of the motive-powers was only 7s. 6d. There are but three little wheels in the clock, and neither weights nor spring; so there is nothing to be wound up.' The electric-clock, as now patented and employed by the Electric-telegraph Company, is somewhat differently constructed. A plate of copper, and another of zinc, buried in the ground to the depth of nine feet, so as to be kept constantly moist, are the generators of the electric current, which is conveyed directly to the pendulum by wires. The pendulum is made of wood, suspended by a steel-spring, and furnished, as usual, with a regulating-bob; the current is conveyed down the wooden rod by wires, to a magnetic coil a little above the bob, and placed in juxtaposition to two permanent magnets, which maintain the oscillation; and about the middle of the pendulum-rod an apparatus is placed on either side, for the purpose of alternately making and breaking the circuit. With the exception of the *break*-apparatus, the whole machine is of extreme simplicity, and little liable to derangement.

Miscellaneous Clock-work.

The applications of clock-work to other purposes than that of measuring time are numerous and important. In all of them, however, the principle is the same—namely, the indication of space, or, what is equivalent, the indication of time or number by mechanical motion. Thus, according to the unit we assume, any amount of space may be indicated either in a regular series, or in a decreasing or increasing series—the increment or decrement taking place progressively, or at intervals, as may be wanted. What can be done with space can be equally accomplished with regard to time or number, and that with an accuracy and precision that no human powers can rival. It was by springs, and weights, and clock-work, that the *automata* which amused our forefathers were moved and directed. Whether they danced or made music, or in whatever way they simulated the conduct of living creatures, it was mechanism that governed their actions—mechanism which would have commanded our admiration the more, that it had been applied to useful purposes. All our *meters*, by which the discharge of gases and liquids are now measured, are but combinations of clock-work; as are also those numerous inventions for *registering* events connected with atmospheric temperature, rise and fall of barometric pressure, direction and force of wind, vigilance of sentinels, and the like.

Thus, by a properly constructed *anemometer* (literally, wind-measurer), not only may the force and direction of the wind be ascertained at any given moment, but the instrument may be made to trace or register the direction from which, and the force with which, the aërial current has swept during every minute of the day—all that is necessary being, to place under the tracing-pencils a clean sheet of paper every twenty-four hours. In like manner, clocks are made for registering the daily fluctuations of the barometer, by means of a pencil floating on the surface of the mercury, and made to traverse a circular card, divided into 365 parts by radii lines, and turned on its centre by the clock once a year. A curious time-keeping method of insuring the presence and attention of night-watchmen has been successfully tried of late years. It consists of a clock with pins projecting round the dial, which can only be pushed inwards at a certain interval, when the watchman's presence and attention are required to unlock the case, and do so, otherwise his neglect, and the exact quarter of an hour at which he was absent, is shewn by the *tell-tale*. Amongst other recent inventions may be noticed a *lock-clock*, to prevent bankers' safes, &c., from being opened except at stated intervals. So also *odometers* (road-meters), or instruments for measuring the space travelled over, whether by pedestrians or wheel-carriages — motion being communicated by the moving body to the clock-work, which is fitted with indices and alarms to indicate any unit of distance required. The same principles have been applied to machines for graduating scales, for engraving tints, and other analogous processes, in which delicacy of line and accuracy of distance are the objects in view.

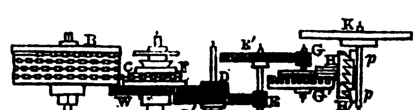
Closely allied to these varieties of clock-work, but evincing a greater degree of scientific skill, are the various machines which have from time to time been invented to lessen the drudgery of long and continuous calculation. The principles upon which the increase and decrease of numbers depend are as fixed as nature herself; and these once known, wheel-machinery of determinate proportions may be constructed to perform every operation in arithmetic with the utmost facility and accuracy. It is well known that in calculations involving the powers and roots of numbers, progression, equations, logarithms, and the like, it not only requires great expertness, but accuracy—an accuracy which is scarcely attainable under the strictest human attention. Such calculations are of indispensable utility in astronomy, navigation, and geography, as well as in general mathematics; and for application, are usually printed in tabular forms, embracing many hundred pages of thick-set figures. To complete such tables with perfect accuracy would require the life-work of several calculators; and yet, by well-arranged machinery, it has been demonstrated that they can be calculated and printed, free from errors, in the course of a few weeks.

The most extensive and ingenious of *calculating-machines* are undoubtedly those invented, and so far perfected, by Mr Babbage. That constructed at the expense of government for the calculation of astronomical and nautical tables, is, we believe, not yet completed, in consequence of some misunderstanding, which caused a suspension of its progress in 1833. This employed 120 figures in its calculation. At a later period, Mr Babbage began another on his own account, intended to compute with 4000 figures! Of the former invention, Sir David Brewster, in 1832, speaks in the following terms:—'Of all the machines which have been constructed in modern times, the calculating-machine is doubtless the most extraordinary. Pieces of mechanism for performing particular arithmetical operations have been long ago constructed; but these bear no comparison, either in ingenuity or in magnitude, to the grand design conceived, and nearly executed, by Mr Babbage.' It appears that the front elevation of the calculating machinery presents seven upright columns, each consisting of eighteen cages of wheel-work, the mechanism of each cage being identically the same, and consisting of two parts, one capable of transmitting addition from the left to the right, and the other capable of transmitting the process of carrying upwards; for it seems that all calculations are by this machinery reduced to the process of addition. There will therefore be 136 repetitions of the same train of wheel-work, each acting upon the other; and the process of addition with which the pen would be going on successively from figure to figure, will here be performed simultaneously, and—as the mechanism cannot err—with unfailing accuracy. The results of the calculating section are transferred by mechanical means to the printing-machinery, and the types are moved by wheel-work, and brought successively into the proper position to leave their impressions on a plate of copper; this copper serving as a mould from which stereotyped plates without limit may be taken.

WATCHES.

Clocks and watches are certainly amongst the most perfect, as, in the civilised world, they are the most indispensable machines ever produced by human ingenuity. 'To become a good watchmaker,' says Berthoud, 'it is necessary to be an arithmetician, in order to find the revolutions of each wheel; a geometrician, to determine the curve of the teeth; a mechanician, to find the forces that must be applied; and an artist, to be able to put into execution the principles and rules which these sciences prescribe. He must know how fluids resist bodies in motion; the effects of heat and cold on different metals; and, in addition to these acquirements, he must be endowed by nature with a happy genius.' No one who has not closely attended to the matter, can conceive the difficulty which has been experienced even in dividing circles for the wheels of a watch into the requisite number of rigorously equal parts, and in 'pitching' them in, or adjusting them one with another. All the resources of art shewn by Ramsden, Troughton, and other eminent mathematical instrument-makers, have been here called into requisition. And as to the delicacy of touch and adjustment necessary in the mere regulation of the mechanism, after being thus accurately made and 'pitched in,' some slight idea may be formed from the fact, which we give in the words of Mr Thomson, that 'a second (a mere pulsation) is divided into four or five parts, marked by the vibrations of a watch-balance, and each of these divisions is frequently required to be lessened an exact 2880th part of its momentary duration!' England has great honour in having advanced the art of watchmaking to its present high condition.

Before entering upon a description of the various parts, we here present the general arrangement of the wheel-work of a common vertical watch—the frame-plates being omitted, and the dial being supposed to be turned downwards. B is the *barrel* or drum, containing the spring which produces the motion. F is the *fusee*, connected with the barrel by the chain *c*. W is the *fusee-wheel*, called also the first or great wheel, which turns with the fusee, and works into the pinion D,



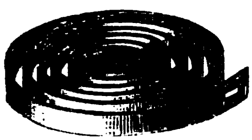
called the *centre-wheel pinion:* this centre pinion, with the centre wheel or second wheel D′, turns once in an hour. The centre wheel D′ works into the *third-wheel pinion* E; and on the same arbor is E′, the *third wheel*, which gives motion to the fourth or *centrate-wheel pinion* G, and along with it the centrate-wheel G′. The

teeth of this wheel are placed at right angles to its plane, and act on the pinion H, called the *balance-wheel pinion;* H′ being the balance-wheel, or *scape*-wheel, or crown-wheel, attached to the same arbor. The balance-wheel acts on the two *pallets p, p*, attached to the *verge* or arbor of the *balance* K; and these being placed at a distance from each other, equal to the diameter of the balance-wheel, and in different places, receive alternately from the scape-wheel an impetus in opposite directions, which keeps up the vibratory motion of the balance. Such is the general arrangement of the powers and motions; we shall now proceed to the analysis.

Mainspring and Fusee.

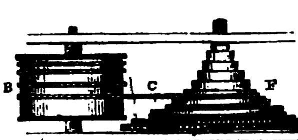
The invention of the mainspring, in place of the weight, was the first pre-requisite to the formation of the watch. But although the mainspring was applied as the maintaining power to time-pieces of a very imperfect description, called watches, about the middle of the sixteenth century, and although the balance had, in such instruments as these, assumed its present form of a vibrating ring, with the greatest weight of course accumulated round a circumference, it was not until the spiral hair-spring was applied to the balance, some time after the invention of the pendulum, as a substitute in clocks for the balance itself, that a comparatively useless machine was converted into a time-measurer nearly as accurate, even in its ordinary form, as the pendulum-clock. Though the invention of the balance-spring, however, was comparatively an early improvement, and the greatest the watch has ever received, we must pass it over in the meantime, till we briefly describe those parts of the mechanism which first rendered the existence of the watch possible at all.

The *mainspring* consists of a coil of thin elastic steel ribbon, enclosed in a miniature barrel or 'drum,' to the inner side of which the outer end of the coil is fixed,



while the inner is fixed to an axis at the centre of the drum, and round which it may be wound or twisted, so as, by its elasticity and recoil, to cause the drum to make as many revolutions as it makes turns itself while it unwinds. Here, then, we have the main power which sets the whole mechanism of the watch in motion. But it is evident that this power, if thus at once applied to the wheels, would cause them to move with less and less rapidity as it became uncoiled, and as its springing power of course became exhausted; so that unless the wheels were so constructed that only the middle turns were required to be in action, and not those in which it is at its greatest or its least power, a force sufficiently equal even for ordinary purposes could not be thus obtained. French spring-clocks, strange to say, are still, in general, made on this defective principle; but English watches and spring-clocks are supplied with a 'fusee,' which corrects the inequalities of the mainspring with a simplicity only equalled by its ingenuity.

The *fusee* is a cone with a spiral groove, attached to the side of the first wheel of the watch, and connected



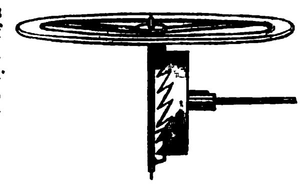
with the barrel or drum containing the mainspring by a chain, hooked, at its ends, to both. The figure to the right, in the above cut, is the fusee; that to the left is the barrel.

In winding a watch, the key is placed on the axis of the fusee, and the chain is wound off the barrel on to the cone of the fusee. When fully so wound, the spring is at its greatest power of recoil; but the chain being then round the smallest part of the cone, the influence of the spring on the wheels is at its least amount; while, just as the power of the spring relaxes and diminishes, the cone enlarges, and its lever-influence hence increases. The fusee, in short, is a variable lever, worked by the mainspring, with more purchase when it has less power, and with less purchase when it has more power. It is a very beautiful contrivance, completely answering the intended purpose, when properly made. By means of a spring contained in the interior of the fusee-wheel, the watch is maintained in motion, while the fusee itself is turned by the watch-key in winding up the mainspring. This is called the *going fusee.* When the watch or spring-clock has no fusee at all —and in very flat watches no fusee *can* be introduced— the barrel is immediately attached to the first wheel. In every case, however, the power of the spring is conveyed through the wheels, by nearly the same arrangement in all watches and clocks, to

The Escapement.

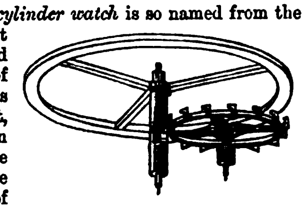
On the peculiar construction of this part of the mechanism, so as best to keep up the vibrations of the balance, the superiority of one watch over another principally depends; though much, of course, also depends on the skill of the workman, and the quality of his materials, in the construction of *every* part of so delicate a machine. The escapement, however, according to its peculiar form, is that by which the watch is chiefly distinguished:—

The *vertical watch* is so named from its old vertical escapement. This



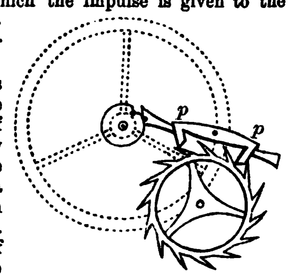
particular mode of escapement is still made in common watches, where it answers sufficiently well; but when applied to clocks regulated by pendulums, is found to be exceedingly defective. The mechanism of this—the *crown-wheel escapement*, as it is technically called—will be readily understood by reference to the preceding figure.

The *horizontal* or *cylinder watch* is so named from the horizontal escapement



of Graham, introduced about the beginning of last century. In this mode of escapement, the impulse is given to a hollow cut in the cylindrical axis of the balance, by teeth of a peculiar form, projecting from a horizontal crown-wheel.

The *lever watch* is so named from the lever escapement of Mudge, in which the impulse is given to the balance by a lever at-



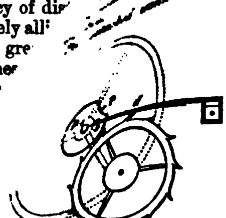
tached to crutch or anchor pallets, *p, p*.

The *duplex watch* is so named from the duplex escapement of Hooke, perfected by Tyrer, in which the impulse is given by a wheel furnished with two sets of teeth. T, T′ are the teeth of repose, lying in the plane of the wheel; *t, t′* are the teeth of impulse, and stand perpendicular to the plane of the wheel; P is

Thus, by a properly constructed *anemometer* (literally, wind-measurer), not only may the force and direction of the wind be ascertained at any given moment, but the instrument may be made to trace or register the direction from which, and the force with which, the aërial current has swept during every minute of the day—all that is necessary being, to place under the tracing-pencils a clean sheet of paper every twenty-four hours. In like manner, clocks are made for registering the daily fluctuations of the barometer, by means of a pencil floating on the surface of the mercury, and made to traverse a circular card, divided into 365 parts by radii lines, and turned on its centre by the clock once a year. A curious time-keeping method of insuring the presence and attention of night-watchmen has been successfully tried of late yea[illegible] It consists of a clock with pins projecting round the [illegible] which can only be pushed inwards at a certain i[illegible] when the watchman's presence and attention ar[illegible] to unlock the case, and do so, otherwise his [illegible] the exact quarter of an hour at which he [illegible] shewn by the *tell-tale*. Amongst other [illegible] may be noticed a *lock-clock*, to prev[illegible] &c., from being opened except at [illegible] also *odometers* (road-meters), or [illegible] ing the space travelled over, [illegible] wheel-carriages — motion b[illegible] moving body to the clo[illegible] indices and alarms t[illegible] required. The same machines for grad[illegible] other analogous [illegible] accuracy of di[illegible]

[illegible] advan- [illegible] successive [illegible] the balance [illegible] and impulse given [illegible] advantage of this [illegible] only one pallet, and [illegible] great accuracy in the [illegible] 'scape-wheel, which is [illegible] the escapements above [illegible] named from the detached escapement of Berthoud, improved by Arnold and Earnshaw, in which the vibrations of the balance are free, or detached from the influence of the crown-wheel, unless at the instant when it receives its impulse and unlocking; the wheels standing still till then.

Closely all[illegible] cing a gre[illegible] machine[illegible] to lesse[illegible] The [illegible] nur[illegible] th[illegible] p[illegible]



In the diagram, P is the main pallet, projecting from the arbor of the balance-wheel, concentric with which is another small pallet *p*, called the *lifting pallet*, which, when the balance is vibrating, lifts a slender spring *s*, so as to set at liberty the tooth held or locked by the detent *d*, which projects from the spring. As in the case of the duplex, the balance here makes two vibrations for each impulse. This mode of escapement, which requires no oil, forms a peculiar feature of the chronometer or marine time-keeper.

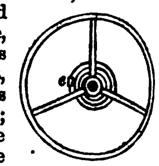
On the respective merits of these different kinds of watches, a few useful hints will be afterwards given. There are many other escapements, but only those now pointed out are in general use.

Balance and Balance-spring.

These are the only other parts of the mechanism of the watch of which it is necessary here to treat.

The balance, as may be seen from the representations of it in connection with the different escapements just noticed, is a wheel finely poised on its axis; the pivot-holes in which it turns being frequently—in chronometers and clocks, as well as in watches—jewelled, or made of small rubies, diamonds, &c., as those of other of the wheels also are, for the sake of durability. The natural effect of an impulse given to such a wheel would be a complete rotation on its axis. This, however, as we have already seen, is convertible, by various escapements, into a vibratory motion. But as in clocks the pendulum was found to be a most invaluable adjunct, absorbing, as it were, in its own more or less extended oscillation, every inequality in the rotation of the wheel-work, or the vibration of the balance, something of work, the mechanism of ea[illegible]. watch-escapements was the same, and consisting [illegible] the balance-spring or hair-transmitting addition fr[illegible], from this analogy, it even other capable of tra[illegible] the pendulum-spring—improperly upwards; for it [illegible] remarks, especially as there is a this machinery [illegible] another description altogether.* There will th[illegible] us as the suggestion of the regulative train of w[illegible] ng, applied to the vibrating mechanism and the p[illegible] ance, in place of either weight or pendu- be goin[illegible] appear, especially after the idea of the be p[illegible] a substitute for the maintaining weight, car[illegible] ggested, this has been held to be a crowning [illegible] in the mechanism of the watch; and the [illegible] its first suggestion has been claimed by no [illegible] three very eminent men—by Dr Hooke; by Hautefeuille, a Frenchman; and by Hüygens, the [illegible] astronomer. It was ultimately proved, that although Hüygens had applied for a patent at Paris in 1674, Hautefeuille had done so several years before; while Hooke had made a similar application in England in 1658. To Hooke, therefore, must be attributed the first idea of the balance-spring.

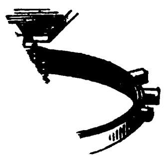
In its application to the balance of a watch, one of the extremities (*e*) of the spring is fastened to a point independent of the balance, while the other is attached near its axis. When the balance is at rest, the spring is inclined neither way, this position being called the point of rest; but when the impulse is given to the balance by the crown-wheel of the escapement, it is clear that now a rotatory motion of the balance cannot take place, even though there should be nothing in the form of the escapement to prevent it; the balance will now only move round so far as the impulse given is able to overcome the elastic resistance of the spring; and when that resistance becomes equal to the impulse given, the balance will stop for a moment, and then be driven back by the elastic recoil of the spring, continuing thus to vibrate so long as the impulse is repeated or the watch is in motion.



The recoil of the spring is sufficient to drive back the balance to a distance nearly double the length of its first motion; this is therefore called the long arc of vibration. But when the motion of the balance is free, with a certain length of spring, the *long* arc of vibration is made in less time than the short one, to which the impulse is given: with a spring of greater length this principle is reversed; whence it was concluded by Le Roy and Berthoud, that equality of time, or *isochronism*, in unequal vibrations, could be more easily obtained by lengthening the spring than by tapering it. In principle, too, the stronger and shorter the spring, the quicker will be its vibrations. Thus effects of an extremely varied description can be produced on the motions of a watch by the slightest difference of length and taper in a hair-spring. And it is thus that the correctness of the time-keeping is essentially dependent on the principle adopted in the formation of this apparently most insignificant little appendage. So much is this the case, that if the hair-spring be isochronal in a free or detached escapement, the time shewn will be the same, notwithstanding changes in the motion of the wheels, or even in the power of the mainspring. In England, where time-keepers have been brought to their greatest perfection,

* This little instrument, the hair-spring, is no less remarkable for the extreme delicacy of its construction, than for the great value which it shews the possibility of giving to a piece of steel, of exceedingly small and insignificant appearance, by manual labour. Four thousand hair-springs scarcely weigh more than a single ounce, but cost often more than £1000! 'The chisel of the sculptor,' as Mr Thomson justly remarks, 'may add immense value to a block of marble, and the cameo may become of great price from the labour bestowed, but art offers *no* example wherein the cost of the material is so greatly enhanced by human skill as in the balance-spring.'

'dered that isochronism is most easily attainable by using the cylindrical helical spring (*s*), which is applied to all marine chronometers.



A recent improvement in watches, or rather in chronometers, invented by Mr Dent of London, consists in coating the ·ing with gold by the electro- ·LECTRICITY), by which means

·tion.

·erfect—in the correction ·spring by a fusee mathe- , in the formation and the ·n of all its wheels and pinions, ·nd execution of its escapement, and ·curacy with which its hair-spring vibrates ·umes—still it will vary in the time it indi- ·s *on every change of temperature*, however slight, unless it be *compensated*.

From what we have already stated in treating of the compensation-pendulum in clocks, the intelligent reader will readily appreciate the difficulties to be here overcome, and will probably conclude, that as in clocks the compensation has been effected by means of the pendulum, so in watches it must have been effected by means of the balance-spring or balance. When completed, the compensation-balance consists of a double or compound rim or ring, the outer part of which is of brass, and the inner of steel, to which the brass is added while in a molten state. The opposite sides of this ring are united by a steel bar, the whole of the steel part, indeed, being filed out of one piece of metal. One half of the ring is then cut or filed away at one side of the bar, and the other half at the other side, as represented in the figure last above given; and the balance is loaded either with small screws, as in that figure, or with sliding weights on each half of the ring, in order to regulate the rate of the chronometer or watch. The compensation, then, is thus effected: an increase of temperature *diminishes* the elastic force of the hair-spring, which would cause the machine to *lose* time; but the same degree of heat expands the outer or brazen part of the ring of the balance more than it does the inner or steel part—brass expanding more than steel by heat, and contracting more by cold—and so, not being able to separate, a curvature of the whole arm of the ring *inwards* ensues, which lessens the inertia or checking weight of the balance; so that the hair-spring now *requires* less force to influence it to the same degree as before; and thus its *loss* of power is *compensated*. On the other hand, cold *increases* the elastic force of the hair-spring, which would cause the machine to *gain* time; but the brass, contracting more than the steel, curves the arm outwards, and increases the inertia, or resistance of the balance, allowing the spring no more influence over it now than it had before.

One defect of this contrivance is, that the balance-spring loses elasticity, by an increase of temperature, at an accumulating rate over the effect produced by the compensation. To remedy this, Mr Loseby has introduced mercury, which, by its fluidity and great thermal expansion, admits of being so adjusted that its effect varies exactly in the same proportion as the change of temperature alters the elasticity of the spring.

The compensation-curb is another instrument for correcting variations in the rate of going from variations in temperature. It limits or extends the length of movement in the hair-spring itself, by a self-moving action, also caused by a difference in the effect of change of temperature on two different metals, and is called a *curb*, from the name of a small piece of mechanism which operates similarly on the balance-spring in regulating a watch by hand.

CHRONOMETERS.

The term *chronometer* is, properly speaking, applicable to all time-keepers, but it is now more usually applied to marine time-keepers only, which are machines of a size between watches and clocks. Some watches, however, made like chronometers in every respect but in size, are called pocket chronometers. But neither of these are anything else than merely such time-keepers as combine all those chief excellences in horological invention just described, including compensation-balance, cylindrical spring, detached escapement, &c., so as to constitute the most accurate time-measurer possible; the purpose of marine chronometers being to discover the longitude at sea; for it is only necessary to ascertain the exact difference in time between two places on different meridians, in order to determine their difference of longitude, or distance eastward or westward of each other. Reverting to what has been already said on this subject, the general reader will at once perceive that so soon as a time-keeper could be made that would keep time with perfect accuracy, such an instrument, set to the time of any seaport, for instance, in Britain—whose precise meridian or longitude was known—and carried abroad in a vessel sailing thence, would afford the means of ascertaining the longitude at sea, by simply observing the instant that the sun reached his meridian there, when, of course, it would be mid-day, or twelve o'clock noon; and at the same time observing the difference between this time and that shewn by the time-keeper, which would necessarily be different if the longitude was different—the amount of the difference giving him his longitude, on the calculation that 15 degrees east or west make *one hour* of time, or 15 geographical miles *one minute*. If, for example, the time-keeper had been set to time at the meridian of Greenwich Observatory [where, in fact, chronometers are now usually adjusted, and where a signal hoisted every day on the instant that twelve o'clock strikes, or rather on the instant that the sun arrives at the meridian there, proclaims the true time of day, on that meridian, to all the mariners in sight of it, that they may be able, without trouble or mistake, to adjust their chronometers accordingly], and if it was but eleven o'clock on the time-keeper thus set, when it was twelve o'clock or mid-day at the time and place where the meridian was taken at sea, then that place must have been in longitude 15 degrees *east* of the meridian of Greenwich; if, on the other hand, it was one o'clock instead of eleven at that moment, the longitude must have been 15 degrees *west*, not east, of the meridian of Greenwich. By knowing also the time when any particular star passed the meridian at Greenwich, the navigator, in a similar manner, could calculate his longitude by an observation of the same star at sea. Lunar observations, eclipses, or the like, might be made use of on similar principles.

It was a clear perception of the fact, that the longitude might thus be at any time determined, could time-keepers be made to measure time with accuracy, that led Sir Isaac Newton and others to recommend to government the offer of a public reward for the accomplishment of so desirable an object; and it was the hope of reaping the splendid reward of £20,000, which government accordingly did offer, that formed the very mainspring to all those high exertions of horological ingenuity which led to the final success of John Harrison, after an unwearied labour of forty years—a success which, in turn, resulted in the present highly advanced state of horology.

USEFUL HINTS.

For the attainment of habits of punctuality, for the regulation of the usual routine of business and of

everyday life, for the morning's timely arousement and the evening's sufficient repose, and for other and innumerable purposes of convenience, necessity, and pleasure, much, in reality, often depends on the judicious selection of a time-keeper. And even the character of a young man has been known to be much influenced by the quality of his watch, the possessor of an accurate time-keeper becoming ambitious to emulate its excellence, and thus gradually acquiring habits remarkable for punctuality. It is therefore to be regretted—even though in many cases a very indifferent time-keeper may be thought all that is required for general purposes—that no efficient instruction can be given to the inexperienced, especially towards the selection of a watch, as none but a workman possessing the highest knowledge of his art is capable of forming a correct opinion of its relative merits. The hints given by a skilful and practical artist himself, however, who has had years of the most attentive and constant experience, cannot but be deemed invaluable; and as such we would especially recommend to the inexperienced in horology, a popular little volume, published by Messrs Boone of New Bond Street—namely, Thomson's *Time and Time-keepers* for the useful as well as pleasing and interesting instruction with which it is stored.

Amongst many valuable hints for the proper selection of time-keepers contained in Mr Thomson's little volume, we shall take the liberty of briefly instancing the following; and first of clocks:—These, in general, measure time more accurately than watches, especially eight-day weight or long-clocks, which are also cheapest. Long and heavy pendulums are to be preferred. A light pendulum shews a clock to be badly constructed, or deficient in power. Steel rods are better than brass, well-seasoned and varnished wood than steel, and compensation-rods than either. The clock should be steadily fixed to the wall, or firmly placed on *three* feet sufficiently far apart, so that the mechanism may be uninfluenced by the oscillations of the pendulum. Clocks are regulated by lengthening the pendulum, to make them lose, and by shortening it, to make them gain; this is very generally done by turning a nut or screw *below* the weight or *bob* of the pendulum, *to the right to gain*, or *to the left to lose;* or, if the screw is *above* the weight, the rule is *reversed*. Many French clocks, and a few old English ones, are liable to derangement in striking, unless the hands are moved rapidly *forward*. The hands of English clocks, in general, may be turned either way without injury, and the same with a watch, unless it has an alarm.

An intelligent, careful man may be safely trusted with the cleaning, adjusting, or repairing of clocks, while a diversity of talent and experience is necessary to qualify him for the manipulation of watches. 'The possessor of a good picture would doubtless inquire into the ability of the artist before he intrusted him to retouch it; and this caution is equally necessary for a watch, as many of the best construction have sustained irreparable injury from the hands of unskilful workmen. Even bad watches—which are by far the greatest number—require the aid of better hands than those which constructed them.' A clever artist may enable even a bad watch to perform tolerably well. Watches should ordinarily be cleaned every second or third year; small, flat, or complicated ones oftener. All require care in handling. They should be regularly wound as nearly at the same hour as possible; and while being wound, should be held steadily in the hand, so as to have no circular motion themselves. When hung up, let the watch have support, and be perfectly at rest; or when laid horizontally, let it be placed on a soft substance for more general support, otherwise the motion of the balance will generate a pendulous motion of the watch, causing much variation in time. Should a watch vary by heat or cold, as when worn or not worn in the pocket, the hands may be set to time; but the regulator should not be altered, if set to the ordinary temperature of the season. Compensation watches, if properly constructed, do not so vary. A trial even of a year or two is no proof of the substantial worth of a watch. Dealers themselves may be deceived. A duplex watch may be very bad, while a vertical one may be very good, so that workmanship is as important as principle. Many low-priced and bad watches have eight or even ten holes jewelled, while many good and costly ones have but four: a hole can be jewelled for three shillings. 'The high-sounding description, the handsome exterior, the offered trial, and enticing cheapness, are effective baits to the short-sighted.' External ornament forms but a small item of expense, and the prices therefore will, in general, point out the comparative qualities of the work in the shop of an artist of known integrity and ability.

The large thick old watch is less absurd than some recently made, little thicker than half-a-crown, or even much smaller, as in the latest and rarest novelty amongst the beautiful and ingenious Genevese watches, some of which little exceed the size of a shilling. The lever watch is capable of great accuracy, and is preferable to the vertical, though the principle of the latter is more generally understood, and more easily repaired; lever watches, however, are neither expensive to repair nor liable to derangement. The horizontal or cylinder watch is liable to great tear and wear, but performs with considerable accuracy. The duplex watch, with a compensation-balance, when well constructed, and treated with ordinary care, will keep time with the greatest accuracy; but being delicate, it does not stand violent exercise: a bad duplex watch is most expensive to repair. The detached watch, the escapement of which is the only one used in marine chronometers, is the most perfect, but requires care. Repeaters are expensive to repair as well as to purchase, but may be as accurate as others. Watches shewing seconds are often useful, and, if well made, are neither expensive nor easily deranged. A watch may be handsome, yet bad; but a good watch is seldom unsightly. The spring for shutting the shells is not so good as the snap; it often allows dust to penetrate to the works. The covers of hunting-watches will not protect the glass when the hunters are very flat. The extreme accuracy of marine chronometers is partly produced by their being kept constantly in a horizontal position. They are only required to shew *equal* time; whether they gain or lose is of little consequence, provided they are regular, and *keep* their known rate.

CHEMISTRY.

THE material world immediately under our observation, including such parts of the earth's crust as have been explored, the plants and animals upon its surface, and the atmosphere which envelops it, is found to consist of sixty-two simple substances, just as all the words which compose a language are resolvable into a few letters. These substances, having hitherto resisted all endeavours to divide or resolve them into any others, are termed the *elements of matter*, or *simple bodies*. By this it is not peremptorily affirmed that there are only sixty-two elementary substances in nature; neither is it maintained that these substances are absolutely simple, and incapable of being reduced to fewer elements, or even, as some chemists have hinted, to a single primary element, of which all other bodies are but conditional phases. All that is here meant is, that at present there are upwards of sixty substances which cannot be reduced, by the known processes of chemistry, to any other condition. The investigation of the laws under which these various elementary bodies have formed the numerous compound substances which we see in nature, and the means by which compound substances can be resolved into their original elements, or simple elements thrown into new combinations, are the objects of the science of Chemistry.

The term *chemistry* is of doubtful derivation; but it seems to have been applied at an early period to various methods of melting or preparing metals, and was identified with the visionary efforts of alchemy, which professed to be the art of transmuting copper and other base metals into gold and silver. It is only within the last seventy or eighty years that chemistry has risen to the rank of a science; but during that period, it has advanced towards perfection with a rapidity unparalleled in the history of philosophy. The applications of chemistry are universal. There is no science so immediately conducive to human comfort. To whatever art or manufacture we turn our attention, we find that it has either been created by chemistry, or owes to it some of its greatest improvements. In the present sheet, it is our object to present a simple and intelligible view of the *principles* of this exceedingly important science, reserving its *applications* in the industrial arts for subsequent treatment.

CHEMICAL ATTRACTION.

When particles of different kinds of matter are brought into contact, they frequently unite, and form new substances, differing widely in many instances from those by whose union they have been formed. This is called *chemical attraction* or *chemical affinity;* because it is said that the particles of certain bodies, having an affinity for each other, will unite, while others, having no affinity, do not enter into union. It might almost be supposed that there are such things as preferences and dislikes among the particles of matter. Thus, if a piece of marble be thrown into vitriol or sulphuric acid, their particles will unite with great rapidity and commotion, and there will result a compound, differing in all respects from the acid or the marble. This is at once an instance of affinity between two substances, and an exhibition of stronger and weaker affinity. The commotion or effervescence in the experiment arises from the disengagement of a gaseous (carbonic) acid in combination with the basis of the marble, in consequence of the sulphuric acid having a stronger affinity for it. When a piece of caustic magnesia is thrown into vitriol, we have a case of simple affinity, with a complete change also of properties. All their elements combine, without any disengagement, and the result is the production of Epsom salts, a compound with properties entirely new. Neither ingredient has been destroyed; they can again be extracted pure from the compound; but they have changed their characters through the force of affinity. But if a piece of quartz or gold be thrown into the acid, no change is produced in either, because the particles of the respective substances have no affinity for each other.

This process of affinity is termed in chemical language *combination*, and is quite distinct from *aggregation*, which is the union of particles of a similar kind, forming a mass which has the general properties of the particles of which it is composed, whatever may be its structure or form. It is also to be distinguished from *mechanical mixture*, in which the particles, although they may be intimately blended, are not amalgamated with each other, so as to lose their own individual properties. The difference between chemical combination and mechanical mixture will be clearly seen from the following example:—If into a crystal bottle we pour a portion of oil and a quantity of water, and shake them well, the two substances can never be made to unite permanently together. Although they appear to do so for a short while after the experiment is made, yet if the vessel be allowed to stand for a sufficient length of time, the particles of water, being heavier than those of oil, will descend to the bottom, while those of the oil will rise upon the top. Here it is evident that no chemical attraction has been exerted between the particles of the two bodies, because no chemical change has taken place. In a word, there has been a mechanical mixture, without any chemical combination. But if with the water in this experiment we add some potash, the results will be very different: the particles of the bodies will intimately combine with each other, and a compound will be formed having properties entirely different from either the oil or the potash. The compound substance thus obtained is the useful article soap.

It sometimes happens that two bodies will readily combine with each other, but if a third body be added, the combination will be destroyed; the first of the two bodies having a stronger affinity for the third than it had for the second. Thus, if magnesia be dissolved in nitric acid, a complete union takes place; but if lime be added to the compound, the nitric acid unites with the lime in preference, and the magnesia, which was formerly dissolved, falls, or is *precipitated*, to the bottom of the vessel. Again, if a piece of aqueous sulphate of copper (common blue vitriol) be suspended by a thread in a glassful of water, the crystals shortly disappear, and the whole fluid becomes tinged with blue. Here the solid is said to be *dissolved*—that is, the cohesion of its particles is destroyed, and the compound is called a *solution* of the solid. Such a solution differs entirely from chemical union, and is merely a very perfect mechanical mixture—the same as if we had dissolved sugar in water, or salt in water. The restoration of cohesion to a body after it has been deprived of it, is exhibited in a great variety of instances. For example, if a quantity of sugar be dissolved in water, and the solution be allowed to stand till the water has evaporated, the attraction of cohesion will take effect between the particles of the sugar, which will again resume the solid form. Here, however, a remarkable circumstance has occurred: whatever the state of the sugar may have been originally, it invariably, in resuming its solidity, assumes a particular form, one of great regularity and beauty. It was formerly opaque, it is now transparent; originally a shapeless mass, it

is now a prism of six sides, surpassing in lustre and symmetry the products of the lapidary's wheel. This solid spontaneous production is called a *crystal;* the process by which it is produced, *crystallisation;* and the science, the object of which is to study the forms of crystals, *crystallography.*

Bodies, whether solid, liquid, or gaseous, are susceptible of assuming the *crystalline* form, and the substances which do so are numberless. The shapes which the crystals take, and the facility with which they assume them, are various. Instances of crystallisation, such as sea-salt, Epsom salts, saltpetre, are familiar to every one. Water, it is well known, when cooled to a certain degree, assumes the form of ice, which is crystalline. There are three methods of producing artificial crystals: first, by dissolving the substance in a hot liquid, and either allowing the solution to cool, or evaporating it by continued heat; second, by making the substance assume the aërial form; and third, by melting it by fire without the presence of a liquid, and allowing it to cool slowly. The first two are the most common methods of forming crystals; and by the third, sulphur, spermaceti, bismuth, &c., may be made to assume the crystalline state. If as much alum be put into boiling water as the water will readily dissolve, crystals will be deposited as soon as the liquid cools. The presence of the atmosphere has considerable influence upon the formation of crystals. If as great a quantity of Glauber salt (sulphate of soda) be dissolved in a flask half filled with boiling water as the water will hold in solution, and the flask be corked, no crystals will be formed as the liquid cools. Remove the cork, however, and crystallisation commences as the air enters, a solid crystalline mass being almost instantaneously formed. If the weather is warm, crystallisation will not perhaps take place even after the solution is cool. In this case, the introduction of a small crystal into the flask will instantly induce the process of crystallisation.

The same body does not invariably exhibit the same form of crystals; there may be several forms of crystals belonging to one body, but in one or other of these it is sure to crystallise, and not according to any other form. It is also to be observed that very different kinds of matter may crystallise after the same model.

The general name for the substance formed by chemical attraction is a *chemical compound;* the substances of which it is composed are called its component or *constituent parts,* or *ultimate elements.* The separation of these is termed *decomposition;* and when decomposition is performed for the purpose of ascertaining the ultimate composition of a body, it is named *chemical analysis.* The reunion of the constituent parts is denominated *chemical synthesis.* Integrant particles of a body differ from the constituent particles thus:—The latter are the most minute parts into which a compound body can be resolved by decomposition, and are hence of a different nature, both with regard to each other, and the substance itself which their mutual union gives rise to. The integrant particles are the most minute parts into which any body can be resolved *without* decomposition.

LAWS OF COMBINATION AND DECOMPOSITION.

There are various laws connected with, and phenomena attendant upon, chemical attraction. While this force can operate only between bodies of a different nature, the qualities which characterise these bodies when separate are changed or annihilated by their combination. Thus, not only their active properties, but their density, temperature, form, colour, taste, smell, and sonorousness are generally affected. Chemical attraction can take place between two, three, or even a greater number of bodies. The force of chemical affinity between the constituents of a body is estimated by that which is requisite for their separation. It has been already remarked that the degree of attraction varies very considerably in different bodies; and it is evident that from this variation all chemical compositions and decompositions take place. The preference of uniting with another substance which any given body is found to exercise, is metaphorically termed *elective attraction* or *affinity.* It is of two kinds, each of which derives its appellation from the number and the powers of the principles which may be brought into contact with each other. When a simple substance is presented to a compound one, and unites with one of the constituents of the latter, so as to separate it from that with which it is combined, and by this means produce a decomposition, it is said to be effected by *single elective affinity.* Some substances, however, will not be thus easily decomposed; and it is found necessary to introduce two or more principles, in order to effect the end in view. When two principles, therefore, are presented to a compound body, and when the principles unite each with one of those of the compound substance, two new substances are formed; and all instances of decomposition in this manner are said to be effected by *double elective affinity.* It is to be observed that all changes effected in this manner are permanent, and that the new compound thus formed cannot be decomposed, until a substance having a more powerful attraction for one of its constituents than they have for each other, is brought into contact with them.

To Sir Isaac Newton we are indebted for the first attempt at a rational explanation of chemical combination. He was of opinion that the minute atoms of certain bodies attract each other with an unknown but enormous force, which begins to exert itself only when the particles are at very small distances from each other, and that, accordingly, this force exerts itself, and the bodies unite when they are brought within the requisite distance. These views slowly made their way into the science; but towards the middle of the eighteenth century, they seem to have been almost universally adopted. The term chemical affinity was substituted for that of attraction, and the strength of the affinity existing in bodies came to be measured according to the order in which they were decomposed. It is unnecessary to mention the various tables of affinity which were published previously to that of Bergman, who, in 1775, gave to the world a copious table of affinities, and appears to have fixed the opinions of chemists in general to his own views of the subject. According to this philosopher, the affinity of each of the bodies, say a, b, c, d, for x, differs in intensity in such a manner, that the degree of affinity in each may be expressed by numbers. He supposed affinity to be elective, in consequence of which, if a have a greater affinity for x than b, if a be presented to the compound bx, a decomposition will ensue, b will be set at liberty, and a new compound ax will be formed.

ATOMIC THEORY.

This theory was not discovered all at once, and immediately acknowledged by chemists; it was gradually brought to light by the repeated experiments of successive philosophers, of whose labours, however, it will be impossible to exhibit a view in this place. To our countryman Dalton, we are indebted for the first development and demonstration of the fact, that bodies unite in definite proportions; and of this law we shall now present as clear and simple a view as possible. Whilst engaged in determining the composition of the two gases called severally carburetted hydrogen and olefiant gas, he discovered that for complete combustion they require *different* but *determinate* quantities of oxygen gas. One volume—that is, any stated measure—of carburetted hydrogen requires two volumes of oxygen gas, whilst a volume of olefiant gas requires three.

The conclusions at which Dalton arrived were, that bodies consist of *atoms,* incapable of further diminution or division; that in chemical combinations it is these ultimate particles which unite; and that in the case above mentioned of the combustion of the two inflammable gases, carburetted hydrogen is a compound of two atoms of hydrogen and one atom of carbon; whilst

olefiant gas is a compound of two atoms of hydrogen and *two* atoms of carbon. The atoms he considered as spheres, and represented them by such symbols as a circle with a dot in the centre, a circle with a vertical diameter, and the like. In this manner the composition of a number of the best known bodies was represented by him, and the ratios of the weights of the atoms of the simple bodies inferred. For instance, he concluded from his experiments that carburetted hydrogen is composed of—hydrogen two, and carbon six; while olefiant gas is composed of—hydrogen two, and carbon twelve. Now, as the latter gas consists of two atoms of hydrogen and two atoms of carbon, then the weights of these atoms are to each other in the relation of one to six. If the weight of the atom of hydrogen, therefore, be represented by one, that of carbon will be six. In this manner, the ratios of the weight of the atoms of all the simple bodies may be ascertained by a careful analysis of the compounds formed by their union.

The combinations of mercury or quicksilver with some other bodies afford an illustration of the theory. Its first compound with oxygen, one of the gases of which the atmosphere is composed, consists of 200 parts of mercury, and eight of oxygen. If, however, the metal be subjected to a considerable degree of heat, it will be converted into a red shining mass, which is also a compound of the metal with oxygen; but in the latter case, eight parts of oxygen have united with 100 parts of the metal. The explanation of this is, that eight is the chemical equivalent of oxygen, and 100 that of mercury. In every successive compound which they make, their proportions form a multiple of one or both equivalents. Every other simple body has, in like manner, its equivalent number, and to its compounds the same rule applies. Innumerable instances of this might be adduced, but these are sufficient to prove the remarkable truth, that when different substances combine by chemical attraction, the proportions of the ingredients are always uniform; that for every atom present of one substance, there is exactly one, or two, or three, &c., of the other. If, for instance, any quantity of sulphur, intermediate between the two combinations of that substance with mercury, be added, it will not combine with it, but remain as a foreign ingredient in the sulphuret of mercury, as the compound is termed. All bodies, however, do not unite in several proportions, thus giving rise to several distinct compounds from two elements; there are many elementary bodies which will only unite with each other in one proportion, so that any two of such substances can only form one compound. This law, however, is not universal, as it is well known that water and alcohol, and water and sulphuric acid, will unite in any proportions. Water will also unite in any proportion with soluble salt, until it becomes completely saturated. Bodies which unite in any proportions form an infinite variety of compounds, and are distinguished by their being united by a weak affinity (not worthy of the name of *chemical affinity*), and also by the compounds formed, differing little from their simple constituents or from each other.

EQUIVALENT RATIOS—SYMBOLS—CLASSES.

The result of investigations of chemical unions has been the formation of scales exhibiting the equivalent ratios of the simple elements, expressed in numbers. For this purpose, it is evident that some body must be fixed upon, and expressed by unity. Hydrogen gas, being the lightest known body in nature, and combining in the smallest proportion by weight with the other simple substances, has been taken as a standard of comparison for the combining proportions or *equivalent numbers* of all other bodies. Oxygen has also, by the continental chemists, been taken as the standard of comparison, and represented by 100. Water is a compound of eight parts by weight of oxygen, with one part by weight of hydrogen; which two gaseous bodies we shall afterwards describe. Whenever hydrogen and oxygen gases are burnt in the proportion stated, they invariably form water; and they cannot be made to combine completely in any other proportion. From this, Dalton concluded that water is a compound of one atom of hydrogen and one atom of oxygen. But the weight of the latter gas being eight times that of the former, then it followed that the atom of oxygen was just eight times heavier than the atom of hydrogen. Hence if the latter be represented by one, then will the former be represented by eight, according to those who take hydrogen as the standard. Those who take oxygen as the standard, and represent it by 100, make the equivalent for hydrogen 12·5; the result is of course the same, the proportion of 12·5 to 100 being exactly the same as that of 1 to 8. These observations lead us to speak of the doctrine of volumes, so generally embraced by chemists. The union of gases is always effected in simple proportions of their volumes; and a volume of one gas combines with an equal volume, or twice or three times the volume of another gas; and in no intermediate proportion.

The impracticability, in many cases, of contriving convenient names expressive of the constitution of chemical compounds, especially of minerals, suggested the employment of *symbols* as an abbreviated mode of denoting the composition of bodies. It was thought that the names of elementary substances, instead of being written at full length, might often be more conveniently indicated by the first letter of their names; and that the combination of elements with each other might be expressed by placing together, in some way to be agreed on, the letters which represent them. The advantage of such a symbolic language was felt so strongly by Berzelius, that he contrived a set of symbols, which he has since used extensively in his writings; and other eminent chemists, as well as mineralogists, believing symbols to be useful, adopted those which Berzelius used. The consequence is, that symbolic expressions, called *chemical formulæ*, are now almost universally employed in the language of chemistry. The following table exhibits the names of

THE ELEMENTS, WITH THEIR SYMBOLS AND EQUIVALENTS.

Elements.	Symb.	Equiv.	Elements.	Symb.	Equiv.
Aluminum, .	Al	13·7	Nickel, . .	Ni	29·6
Antimony (*Stibium*), . .	Sb	129·	Niobium, . .	Nb	
Arsenic, . .	As	75·	Nitrogen, .	N	14·
Barium, . .	Ba	68·5	Norium, . .	No	
Beryllium, . .	Be	6·9	Osmium, .	Os	99·6
Bismuth, .	Bi	213·	Oxygen, . .	O	8·
Boron, . .	Bo	10·9	Palladium, .	Pd	53·3
Bromine, .	Br	80·	Pelopium, . .	Pe	
Cadmium, . .	Cd	56·	Phosphorus, .	P	31·
Calcium, . .	Ca	20·	Platinum, . .	Pt	98·7
Carbon, . .	C	6·	Potassium (*Kalium*), . .	K	39·
Cerium, . .	Ce	47·?	Rhodium, . .	R	52·2
Chlorine, . .	Cl	35·5	Ruthenium, .	Ru	52·2
Chromium, .	Cr	26·7	Selenium, . .	Se	39·5
Cobalt, . .	Co	29·5	Silicium, . .	Si	21·3
Copper (*Cuprum*),	Cu	31·7	Silver (*Argentum*),	Ag	108·
Didymium, .	Di	50·?	Sodium (*Natrium*),	Na	23·
Erbium, . .	E		Strontium, . .	Sr	43·8
Fluorine, .	F	19·	Sulphur, . .	S	16·
Gold (*Aurum*), .	Au	197·	Tantalum, . .	Ta	184·
Hydrogen, .	H	1·	Tellurium, .	Te	64·
Iodine, . .	I	127·	Terbium, . .	Tb	
Iridium, . .	Ir	99·	Thorium, .	Th	59·6
Iron (*Ferrum*), .	Fe	28·	Tin (*Stannum*), .	Sn	58·
Lantanium, .	La	47·?	Titanium, .	Ti	25·
Lead (*Plumbum*),	Pb	103·7	Tungsten or Wolfram, . .	W	92·
Lithium, . .	Li	6·5	Uranium, .	U	60·
Magnesium, .	Mg	12·	Vanadium, . .	V	68·6
Manganese, .	Mn	27·6	Yttrium, .	Y	
Mercury (*Hydrargyrum*), .	Hg	100·	Zinc, . . .	Zn	32·6
Molybdenum, .	Mo	46·	Zirconium, .	Zr	33·6

Applying these symbols, HO represents water—that is, one equivalent of hydrogen and one of oxygen; SO_3, sulphuric acid—that is, one equivalent of sulphur and three of oxygen; and in the same manner, NO_5, nitric acid; HCl, hydrochloric acid; and so on. The

brevity and lucidity of the system are admirable; and to the chemist, a few lines of properly constructed formulæ convey more information than pages of description, and with less risk of misconception and error.

For the convenience of study, the sixty-two elementary substances have been arranged into classes. One system of classification, and that which we adopt, is dependent upon the elements being metallic or non-metallic. 1*st*, The NON-METALLIC elements are thirteen in number—namely, oxygen, hydrogen, nitrogen, carbon, boron, silicon, sulphur, chlorine, bromine, iodine, fluorine, selenium, and phosphorus. Oxygen, chlorine, bromine, iodine, and fluorine, having a tendency to combine with almost all other substances, and their union being generally accompanied by light and heat, have been termed *supporters of combustion;* and the four latter, from their similarity in habitude and properties, have received a common termination—namely, *ine.* For the same reason, carbon, boron, and silicon have *on* annexed. 2*d*, The METALLIC elements are forty-nine in number, of which the more important are—potassium, sodium, barium, strontium, calcium, magnesium, aluminum, chromium, zinc, manganese, nickel, cobalt, iron, lead, silver, mercury, copper, bismuth, cadmium, gold, platinum, antimony, tin, and arsenic. The more rare, and, commercially speaking, less important metals, are—beryllium, cerium, didymium, erbium, iridium, lantanium, lithium, molybdenum, niobium, norium, osmium, palladium, pelopium, rhodium, ruthenium, selenium, tantalum, tellurium, terbium, thorium, titanium, tungsten, uranium, vanadium, yttrium, and zirconium.

ACIDS, SALTS, METALLIC OXIDES, EARTHS, ALKALIES.

Acids are a most important class of chemical compounds, and have the following characteristic properties:—The greater number of them have a sour taste, and are very corrosive. With few exceptions, they change vegetable blues to red, they are mostly soluble in water, and they unite with the alkalies, earths, and metallic oxides, forming what are called *salts*—an order of bodies of the highest importance in the arts, manufactures, &c. Some acids are destitute of a sour taste, but their affinity for the three classes of bodies above named is a universal characteristic. Acids are all compound bodies, and some of them have more than one *basis* or radical. There are a number of acidifying principles, but oxygen is the most extensive one. The acid is distinguished by the name of its characteristic ingredient, and its degree of oxidation—that is, the quantity of oxygen it contains, is marked by the termination in *ous* or *ic*, or by the prefix *hypo* (under). The highest degree of oxygenation is marked by the termination *ic*, as nitric acid, and the salt which is formed from it is made to terminate in *ate*, as nitrate of potash; the next by that of *ous*, as nitrous acid, and the salt which is formed from it is made to terminate in *ite;* and the lowest by *hypo*, as the hyponitrous acid. Sometimes oxygen combines in a greater quantity with the acidifiable radicals, in which case the product is said to be superoxygenated. All acids are not susceptible of these various degrees of oxygenation, some being limited to only one. There are a considerable number of acids; but of the more important there are few, and these we shall notice as we come to treat of the several elements.

A *salt* is the term usually employed to denote a compound, in definite proportions, of acid matter with an alkali, earth, or metallic oxide. When the proportions of the constituents are so adjusted that the resulting substance does not affect the colour of infusion of litmus or red cabbage, it is then called a *neutral* salt, because the peculiar powers of both bodies are suspended and concealed; they are rendered neutral or inactive. When bodies combine in such a way as to satisfy their mutual affinities, they are said to *saturate* each other. When the predominance of acid is evinced by the red of these infusions, the salt is said to be acidulous, and the prefix *super* or *bi* is used to indicate this excess of acid. If, on the contrary, the acid matter is deficient, or short of the quantity necessary for neutralising the alkalinity of the base, the salt is then said to be with excess of base, and the prefix *sub* is attached to its name. These must be understood, however, only as general rules. There are exceptions to be found in the case of some salts, as the compounds formed by an acid and an alkali, an earth, or a metallic oxide, are denominated. For example, a certain salt formed by nitric acid and lead, though the acid be perfectly neutralised, reddens vegetable blues; and a salt formed by boracic acid with soda retains the powers of an alkali, in the respect in question, though with a double proportion of acid in it. A *double salt* is a compound of two salts—as, for example, tartrate of potassa combined with tartrate of soda, or sulphate of potash and sulphate of alumina in ordinary alum.

Metals, such as iron, copper, lead, &c., are familiarly known to every one, but there are a great many others which are very rarely to be met with. The following are some of the characters which distinguish metals from other bodies:—They are for the most part hard and heavy, and are all opaque; insoluble in water; they possess a peculiar lustre; admit of being so highly polished as to reflect light; are capable of being melted by heat, and of recovering their solidity by cooling; most of them may be extended by hammering, and all are rapid conductors of electricity. They are of various colours, and require different degrees of heat to fuse or melt them. They generally occur in the earth in what are called *veins* (excepting iron, which is found in *strata*), and are seldom found in the pure metallic state, but generally in combination with some other substance, in which state they are called *ores*. The metals, which are all simple bodies, will be individually noticed afterwards. (See also METALS AND METALLURGY.) Most of them, when subjected to heat until they become melted, combine with the oxygen of the atmosphere, and form what are called *oxides*. Oxides are destitute of those properties which distinguish the metal from which they are formed. Instead of being bright, shining, elastic, and ductile substances, they are generally a dry, earthy-looking powder. Other substances, besides metals, however, are capable of being converted into oxides; and it must be kept distinctly in view, that in every case there is not so much oxygen imparted as will produce *acidification*. Oxygen frequently combines in various proportions with a substance, rendering it an oxide, but without advancing it to the state of an acid. In order to distinguish each compound thus formed, the language of chemistry is very systematic. The first is called a *proto*xide; the second, a *deut*oxide or *bin*oxide; the third, a *trit*oxide or *ter*oxide; and the highest degree of oxidation, a *per*oxide. The Latin term *sesqui* (one and a half) denotes that the elements exist in a compound, in the ratio of one and a half—as the sesqui-carbonate of ammonia. When a simple non-metallic substance combines with another, with a metal, or with a metallic oxide, the name of the compound terminates in *uret*—as carburet of iron, sulphuret of mercury, &c.

The term *earths* was formerly, and is still, but in a modified sense, applied to several substances which compose all the various rocky substances, clays, and soils which constitute the crust of the globe. They are tasteless, inodorous, dry, uninflammable, sparingly soluble, difficult of fusion, and of moderate specific gravity. These bodies will be more particularly described when we come to treat of their metallic bases.

Alkalies may be defined as bodies which combine with acids so as to impair or neutralise their activity, and produce what are called salts. They are distinguished by properties the reverse of acids, and the two classes are generally looked upon as antagonist substances. Besides the power of neutralising acids, there are four alkalies—namely, potash, soda, ammonia, and lithia—which possess the following properties in a high degree:

They change vegetable blue to green, red to purple, and yellow to a reddish brown; they have an acrid and urinous taste; they are powerful corrosives of animal matter, with which they combine so as to produce neutrality; they also unite with oils and fats, forming the well-known substance soap; they combine with water and alcohol in any proportion. Four of the earths —namely, lime, baryta, strontia, and magnesia—possess alkaline properties to a considerable extent, and are hence called *alkaline earths*. These bodies differ from the pure alkalies, inasmuch as they become insoluble in water when neutralised by carbonic acid. Moreover, alkalies possess the power of changing vegetable colours *after* being saturated with carbonic acid, and by this criterion they are distinguished from alkaline earths.

It was long observed that the properties of earths very nearly resemble those of the compounds of oxygen and metals called metallic oxides; but it remained for the brilliant genius of Sir Humphry Davy to shew that both the earths and alkalies are metallic oxides. It thus appears, then, that the globe is one vast mass of various kinds of metals, disguised by various substances, but chiefly by oxygen. Earths and alkalies are simply metallic oxides; whilst a further impregnation of these substances with oxygen produces an acid; and, lastly, the union of acids with alkalies, &c., gives rise to that very numerous and important class of substances called salts.

I. NON-METALLIC ELEMENTS.

Oxygen.

Oxygen gas occurs in a state of freedom in the atmosphere, of which it constitutes about one-fifth part by volume. In combination with other elementary substances, oxygen is present in water, sandstone, limestone, clay, and other rocks, as also in the materials derived from the vegetable and animal kingdoms. Indeed, it is probable that one-half of the entire globe is composed of free or combined oxygen.

The most modern method of preparing this gas is to prepare a mixture of four parts pulverised chlorate of potash, and one part binoxide of manganese; introduce the mixture into a retort (fig. 1), or a florence flask with

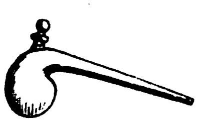


Fig. 1.

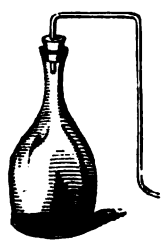


Fig. 2.

bent tube attached (fig. 2), support the vessel on a

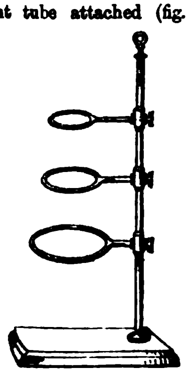


Fig. 3.

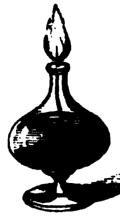


Fig. 4.

retort-stand (fig. 3), and apply heat from a gas-jet or spirit-lamp (fig. 4.) Oxygen is very readily given off, and may be collected by conveying the exit tube beneath jars filled with water and standing on the shelves of the pneumatic trough (fig. 5.) The gas may likewise be

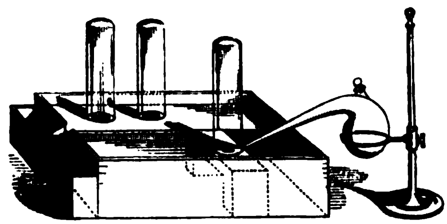


Fig. 5.

obtained from red oxide of mercury, nitrate of potash, chlorate of potash, or binoxide of manganese, taken separately. In the latter instances, however, a very high temperature is required, and accordingly the materials must be placed in an iron or fire-clay retort, and the heat of a furnace applied.

Oxygen is a colourless, odourless, and tasteless gas, which has never been liquefied nor solidified. It is slightly heavier than ordinary air, having the density of 1105·6 as compared with air taken as 1000. It is soluble in water to the extent of three volumes and a half in every 100 volumes of water. This gas is not combustible, but is a most powerful supporter of combustion; so that a candle, with simply a red wick, or a splinter of wood which has been on fire and then blown out, leaving a red tip, instantly bursts into full flame when plunged in oxygen, and thereafter burns with great rapidity. Sulphur, phosphorus, and even a spiral of iron wire or a watch-spring, ignited and surrounded by an atmosphere of oxygen, retained within proper vessels (figs. 6, 7 and 8), burn with dazzling

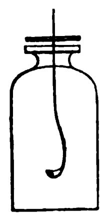


Fig. 6.

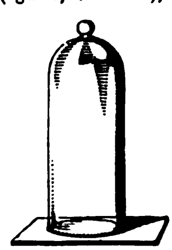


Fig. 7.

Fig. 8.

brilliancy. Indeed, it is the presence of this gas in the atmosphere that enables our gas-jets, candles, and coals to burn.

As an agent in respiration, oxygen is of vast importance. Animals inhale it from the atmosphere at every breath, and were they deprived of it for a few minutes, they would cease to live. At each inspiration, oxygen passes into the lungs, there meets the blood, in which it is dissolved, and carried into every nook and corner of the animal frame. There it supplies air to burn minute particles of fat, &c., and in this manner assists in keeping up the temperature of the animal system. Pure oxygen cannot, however, be inhaled for a length of time without alarming symptoms beginning to manifest themselves. After an hour or so, the breathing of the animal becomes more hurried, and the circulation of the blood more rapid. This period of excitement gives place to one of great debility, and death occurs in six to twelve hours.

Oxygen is essential to the germination of plants, and likewise to their growth. During the active and healthy growth of the vegetable kingdom, this gas is exhaled by them in large quantity; the same remark applies to sea-weeds and other plants growing in water.

Animals inhabiting the water are thus supplied with much of the oxygen they require, which, being dissolved in the water, passes through the gills, and from thence enters the system, and performs the same functions as in the case of the land animal.

The compounds of oxygen with other elementary substances are divided into three classes—*acid oxides*, such as sulphuric acid, a compound of sulphur and oxygen; *basic oxides*, such as *rust* (peroxide of iron), made up of iron and oxygen; and *neutral oxides*, such as water, composed of hydrogen and oxygen.

Ozone.—It has been long known to electricians that a peculiar odour accompanied the working of frictional electrical machines, but it is only recently that this odour has been recognised as pertaining to a distinct gas or air composed of three atoms of oxygen rolled into one. Besides being produced in the air contiguous to an electrical machine in active operation, it is likewise formed when a piece of phosphorus is placed in a jar of air and half covered by water. The production of this curious substance may be observed by suspending in the jar a slip of paper moistened with solution of iodide of potassium and starch, which is changed to a rose-red colour, and ultimately to a purplish violet. Another method of preparing ozone is to place a little ether in a jar, and thrust into the air, containing the ether vapour diffused through it, a heated glass-rod. Much heat will now be produced from the partial combustion of the ether, and the test-paper will indicate the production of ozone. Very little is known about the natural distribution and source of this gas, but it is generally present in the atmosphere, especially in winter. Much more is found in country districts than in towns, and this is accounted for by the rapidity with which ozone combines with and destroys any vegetable or animal matter in a state of putrefaction. So much is this the case, that a piece of bad-smelling meat, suspended in a jar containing the gas, very quickly loses all disagreeable odour. Ozone is, doubtless, therefore of great use in clearing away infectious and other organic matters from our atmosphere, and this it accomplishes from the great oxidising powers which it possesses. Another property which it exhibits in a marked degree is that of bleaching; and though, as yet, it has never been used in our bleach-works, yet it appears very probable that the present household process of bleaching—namely, by laying out and exposing the moistened cloth to the action of the sun and air—owes much of its efficacy to the presence of ozone in the atmosphere.

Hydrogen.

Hydrogen is found in an uncombined state in minute cavities in the rock-salt of Wieliczka; but the quantity so distributed is very small. It generally occurs chemically united with other elements, as in water, where the hydrogen is associated with oxygen. It is likewise present in coals, and the majority of substances derived from plants and animals.

The most convenient method of preparing the gas is to introduce into a bottle (fig. 9) a few fragments of zinc, some water, and a little sulphuric acid (oil of vitriol). The gas begins immediately to come away, and if a cork, with a bent glass or metal tube passing through it, be inserted in the bottle, the gas may be easily conveyed into jars filled with water, and standing on the pneumatic trough (fig. 5 or 10). In this experiment, iron filings may be substituted for the zinc, and hydrochloric acid for the sulphuric acid, provided such only be at hand.

Fig. 9.

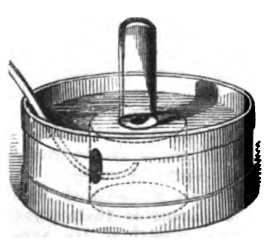


Fig. 10.

Hydrogen, when pure, is a colourless, tasteless, and odourless gas. When freshly prepared, however, it always possesses a peculiar odour, which is due to the presence of an oily compound of carbon and hydrogen. The pure gas dissolves in water to the extent of 1½ volumes in every 100 of water. It has never been liquefied nor solidified. It has the specific gravity of 69·2, air being taken as 1000, and oxygen 1105·6, and is consequently 14½ times lighter than air, and 16 times lighter than oxygen. This lightness of hydrogen may be observed by uncovering a jar containing it, when, in less than one minute, the gas will be found to have risen out of the vessel; or by filling a small balloon with hydrogen, when the former will rise to the roof, and remain there some time. Even soap-bells will rise and float through the air, when they are dexterously blown from a stream of this gas. Hydrogen is a combustible gas, burning with a pale-yellow flame, but it is a non-supporter of combustion, and will not allow a candle or any other light to burn in it. Though little light is evolved when hydrogen is burning, yet the heat given off is very great; so much so, that an arrangement called the oxyhydrogen blow-pipe, at the mouth of which hydrogen is burned with oxygen or air, produces the most intense heat known. During the ordinary combustion of hydrogen, it quietly combines with the oxygen of air, and produces pure water; but if the hydrogen is previously mixed with common air or pure oxygen, and then set fire to, a more or less violent explosion is the result. The proportions required to produce this explosive mixture are two volumes of hydrogen to one of oxygen.

By far the most important compound of hydrogen with any other substance is that with oxygen, forming the indispensable fluid which covers nearly two-thirds of our globe—*water*. Water is thus an oxide of hydrogen—a compound never found absolutely pure in nature. In the ocean it is salt and brackish, from the presence chiefly of chloride of sodium; in springs it is either carbonated—that is, contains carbonic acid; sulphureous, from the presence of sulphuretted hydrogen; chalybeate, from the union of the sulphate or carbonate of iron; and so on, according to the nature of the mineral ingredients through which it percolates. When it contains a chemical compound of lime, it is said to be *hard*, and in this condition it decomposes soap, and destroys its detergent properties. The impurity of water may thus arise either from chemical union or mechanical mixture with other bodies. The latter can generally be removed by filtration; but when the union is chemical, distillation (a process to be afterwards described) is necessary to produce a pure liquid.

Hydrogen also unites with the other supporters of combustion; but the compounds, except hydrochloric acid (to be afterwards mentioned), are not of any great importance.

Nitrogen.

This element occurs uncombined in the atmosphere to the extent of four-fifths of its entire bulk, and, chemically united with other substances, it exists in the native nitres, as also in plants and animals.

Nitrogen may be prepared by burning phosphorus in a confined portion of air, when the combustible abstracts the oxygen and leaves the nitrogen (fig. 11). This experiment is best accomplished under a bell-jar

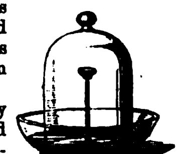


Fig. 11.

closed at the top, and the lower part open, but surrounded by water. As the oxygen disappears by uniting with the phosphorus, the water rises in the jar, till, when combustion has ceased, about four-fifths of the original bulk of air will be left as nitrogen.

This gas is colourless and transparent, without odour or taste. It has a specific gravity of 971·37, and has resisted all attempts at liquefaction or solidification. In the ordinary sense of the term, it is not combustible, neither does it support combustion. Consequently, a lighted candle is immediately extinguished when it is plunged into a jar of the gas (fig. 12). An animal immersed in nitrogen soon dies; not that it is a poison, but because, while the animal is inhaling this gas, it is debarred from inhaling oxygen, which is essential to life. The chief use of so much nitrogen being present in the air seems to be the dilution of the oxygen to that strength which is safe for the purposes of combustion and respiration. Nitrogen is less soluble in water than oxygen, and has no action on vegetable colours.

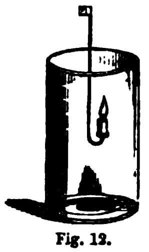


Fig. 12.

The atmosphere consists mainly of nitrogen and oxygen, in the proportion (if these ingredients be alone regarded) of 210 oxygen to 790 nitrogen, by measure; and of 231 to 769 by weight. Common atmospheric air alone, contains as constant ingredients in every situation, a little carbonic acid gas, vapour of water, ammonia, nitric acid, and ozone. In volume, the carbonic acid forms about 1-2000th part; or 0·5 parts in 1000 by measure; which is equal to 0·75 parts in 1000 by weight. Its proportion is greater in summer than in winter, during night than in the daytime, in elevated situations than on the plains. The watery vapour is more variable in proportion. The mean is supposed to be about 10 parts in 1000 by weight, 15 by volume. The quantity is determined by the temperature, heat being the sole cause which sustains the vapour in the aërial state. The free nitrogen and oxygen of the atmosphere are there merely as a mechanical mixture, and not as a chemical compound. The oxygen performs the chief part in the process of respiration, the nitrogen acting in a negative capacity as a simple diluent.

Nitrogen combines with the majority of the supporters of combustion. With oxygen it unites in no fewer than five proportions—namely, one equivalent of nitrogen to one, two, three, four, and five of oxygen respectively; or, one volume of nitrogen to a half, one, one and a half, two, and two and a half of oxygen. Of those compounds, by far the most important is nitric acid, or the *aquafortis* of the alchemists.

Nitric Acid occurs largely native in combination with potash, as nitrate of potash, or saltpetre; and with soda, as nitrate of soda or cubical nitre. It is likewise found to a minute extent in the atmosphere, and in spring-waters whose source is in the neighbourhood of church-

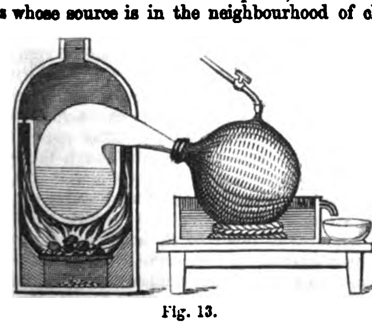


Fig. 13.

yards. It can be most economically prepared by placing equal weights of nitrate of soda and sulphuric acid in a retort (fig. 13), and applying heat. The nitric acid distils over, and is collected in a receiver surrounded by cold water. What is left in the bulb of the retort is the sulphate of soda, a compound of soda and sulphuric acid. Nitrate of potash may be substituted for the nitrate of soda in the above experiment. As thus prepared, nitric acid generally contains a little hydrochloric acid, sulphuric acid, and iodine, obtained from the salt employed.

When pure, nitric acid is colourless, with a peculiar odour, and an intensely sour taste even when diluted with much water. Subjected to bright light, a portion of the acid is decomposed, producing nitrous acid, which causes the remaining acid to assume a yellow tint. Exposed to the air, the strong acid fumes, from the union of the acid vapour with the water vapour of the air. The affinity of nitric acid for water is so great, that a bottle well filled with the acid, and left unstoppered, sucks in so much water from the air that it fills up and runs over. The commercial acid has a density of 1424, water being taken as 1000, contains two-fifths of its weight of water, and boils at 250° F. The strongest acid, or *double* aquafortis, holds one-seventh of its weight of water, has the specific gravity of 1522, and boils at 184° F. The latter strength is employed, along with sulphuric acid, in preparing *gun-cotton*. *Anhydrous nitric acid* has recently been produced by passing a stream of dry chlorine over dry nitrate of silver. It is thus obtained in the crystalline form, melts at 86° F., and boils at 113° to 122° F.

Nitric acid has very remarkable effects upon water with regard to the production of heat. If diluted with half its weight of water, heat is evolved; but if the water be in the state of snow, intense cold is the result. Hence this compound is employed to produce great degrees of cold. If nitric acid, highly concentrated, be thrown upon phosphorus, charcoal, or oil of turpentine, it inflames them. It is very extensively used in the arts, particularly for the purification of gold, for etching on copper-plates, &c.

Nitric acid forms a numerous and important class of salts, having the generic name of *Nitrates*—such as nitrate of silver, nitrate of potash, &c. Some of these we shall notice afterwards. *Nitrous acid* is a compound of the same kind as nitric acid, but with a lesser quantity of oxygen. Amongst the other compounds of nitrogen and oxygen, that entitled the *protoxide of azote*, or *nitrous oxide*, is the most remarkable. It is prepared by heating the nitrate of ammonia in a retort when the salt fuses, and then passes entirely into water and nitrous oxide. The latter is a colourless and transparent gas, with a slight agreeable odour, and a sweet and pleasant taste. Davy discovered that we may breathe it for a short while without any effect being produced, except an exhilaration of the mind; hence the term *laughing gas*, which is sometimes applied to it. Combustibles burn in it more brilliantly than in common air. Faraday has succeeded in solidifying this gas under a pressure of fifty atmospheres at 45°, and is of opinion that it might be employed in this state with greater advantage than solid carbonic acid, for producing intense cold by its evaporation *in vacuo* when mixed with ether. There is also a *nitric oxide* and a *hyponitrous acid;* but these do not require minute detail. Nitrogen combines likewise with chlorine and bromine.

Ammonia, or *Hartshorn*.—This important substance is formed by the combination of nitrogen with hydrogen, and is obtained in the state of gas from the salt called *sal ammoniac*, which is a compound of hydrochloric acid and ammonia. This substance is introduced into a retort, along with quicklime, and then subjected to heat. Ammonia is driven off in the form of gas, and is collected in glass jars standing over mercury. Ammoniacal gas is colourless, has a strong pungent smell, an acrid caustic taste, and cannot be drawn into the lungs.

Its specific gravity is 589. Water dissolves 780 times its volume of this gas, and the solution obtained by passing the gas into a vessel containing water, constitutes the commercial hartshorn, which is employed for chemical purposes and as an agent in our manufactures. When the gas is mixed with chlorine, a sudden combustion and detonation take place. The chlorine unites with the hydrogen of the ammonia, and forms hydrochloric acid, whilst the nitrogen is disengaged in the state of gas. The muriatic acid formed combines with a portion of ammonia, and forms sal ammoniac. Ammonia is an alkali, and possesses the properties distinguishing this class of substances in a very decided manner. It of course neutralises acids, and the salts which it forms are numerous, and of considerable importance.

Carbon.

Carbon occurs pure and free in the diamond, and combined with other elements in graphite (plumbago or black-lead), anthracite coal, ironstone, limestone, as also in the wood of all plants, and the fat and muscle of animals. It is prepared by burning wood, coal, &c., in close vessels. When wood is employed, the carbon is called *charcoal*, and when coal is the original material, the term *coke* is applied to the product. When bones are thus treated, they yield *ivory black*, *bone black*, or *animal charcoal;* and when oily substances are imperfectly burned, they produce much *lamp black*. Many varieties of carbon, especially the *bone black*, have the power of absorbing gases and coloured matters, and hence are useful in deodorising places where disagreeable smells are prevalent, and in clarifying and decolorising liquids—such as sirup of sugar. Carbon burns in oxygen with considerable brilliancy, although in common air it emits but a feeble light. If carbon be burned in a close vessel, filled with oxygen, the carbon will be entirely consumed, and the oxygen so much changed, that a lighted taper put into it is immediately extinguished. Carbon combines with all the supporters of combustion, and with oxygen forms carbonic acid.

Carbonic Acid, discovered by Black in 1757, and described by him under the name of *fixed air*, may be prepared at the pneumatic trough, by putting into a retort or bottle some chips of marble, or carbonate of lime, and an ounce of hydrochloric acid, previously mixed with two ounces of water. An effervescence takes place between the acid and the marble, carbonic acid gas being given off, which can be collected in jars. Carbonic acid is fatal to animal life, and the gas will extinguish a candle introduced into it. A candle cannot burn in a mixture of four measures of atmospheric air and one of carbonic acid; and no animal can live in air which contains sufficient carbonic acid to extinguish a candle; hence the practice of letting down a burning taper into old wells, pits, brewers' tuns, and the like, before any one ventures to descend. If the light is extinguished, the air is certainly impure; and there is generally thought to be no danger if the taper continues to burn; but instances have been known of the atmosphere being sufficiently loaded with carbonic acid to produce insensibility, and even death, and yet not so foul as to extinguish a candle. Water, under the ordinary pressure of the atmosphere, dissolves a certain amount of carbonic acid, and under pressure, may be saturated with it, in which state it sparkles when poured from one vessel to another. All kinds of spring and well water contain carbonic acid absorbed from the atmosphere, and to its presence they are partly indebted for their pleasant flavour. Boiling deprives water of its carbonic acid, whence its insipid taste. The agreeable pungency of beer, porter, ale, and many other beverages, is in a great measure owing to its presence; by the loss of which, on exposure to the air, they become flat and stale. Thus, though deleterious when breathed into the lungs, carbonic acid is exhilarating and wholesome when taken in moderate quantities into the stomach.

Carbonic Oxide is produced when carbonic acid is passed over red-hot charcoal, contained in an iron or porcelain tube. It is likewise formed in our grates, when carbonic acid, generated at the lower bars, rises through a stratum of red-hot coal. This change is evident from the blue flame of carbonic oxide, which is observed in our fireplaces, especially during frosty weather. It contains less oxygen than carbonic acid, but is even more poisonous.

Oxalic Acid is another well-known combination of carbon with oxygen, and may be formed by digesting sugar along with nitric acid. The acid is deposited in small crystals, which have an intensely acid taste, and when taken internally, even in small quantities, destroy life. It combines with bases, and forms a genus of salts called *oxalates*. Carbon is capable of uniting with chlorine in three different proportions, with bromine in one or two, and with iodine in two.

There are many combinations of carbon with hydrogen, and much uncertainty prevails both with regard to their number and nature; they are all designated *hydro-carbons*, or more properly *hydrocarburets:—Carburetted hydrogen*, or *marsh-gas*, a spontaneous production of nature in mines, &c., is one of the most terrific instruments of destruction, and a great obstacle to human industry; for, by mixing with a certain quantity of common air, it acquires the property of exploding when accidentally kindled, and thousands of human lives have fallen sacrifices to its violence, until Sir Humphry Davy's invention of the safety-lamp greatly divested it of its terrors. (See MINING.) Davy's safety-lamp consists of a common lamp surrounded with wire-gauze. On analysing the carburetted hydrogen, or fire-damp, Sir Humphry Davy found that it would not explode when mixed with less than six times, or with more than fourteen times, its volume of atmospheric air; that air rendered impure by the combustion of a candle will not explode fire-damp, though the candle will still burn for a time; and that if a candle be burnt in a close vessel, with small apertures only above and below the flame, no explosion will ensue. The flame within will be enlarged, but no explosion take place; and it was found that the gas usually generated in mines will not explode in a tube less than one-eighth of an inch in diameter.

Bicarburetted hydrogen is the chief, although not the most abundant ingredient in *coal-gas*, now so generally used for illumination; the other ingredients are carburetted hydrogen, hydrogen, and carbonic oxide. Coal-gas is made by introducing a quantity of bituminous coal into a large cylinder called a retort, shut at one end, and furnished with a mouthpiece at the other, for closing or opening it; there is also a tube for carrying off the gas and other products as they form. A quick strong heat is applied round the cylinder, and a vast quantity of gas, composed of the four ingredients just mentioned, is thus extricated, with tar and an ammoniacal liquor, both of which are condensed by passing through pipes immersed in cold water. There is a great difference in the relative proportions of the gases in the mixture, as also in the quantity of tar, according to the quality of the coal, and the mode of applying the heat. A slow heat gives much tar and little gas, and that little of a poor quality; a quick heat gives much gas, of good quality, and less tar. Owing to these and other causes, the illuminating power of coal-gas varies much. Before it is let through the conducting tubes for public consumption, it is well agitated in contact with a mixture of lime and water, or passed through strata of loosely strewed hydrate of lime: it is thus deprived of much of its smell, and also of some of its illuminating power. (See LIGHTING.) There are other less important compounds of carbon and hydrogen, and the whole correspond with the law of multiple combination already described. *Naphtha* and *naphthaline* are hydrocarburets; the former a

transparent volatile fluid, the latter a transparent volatile solid, which assumes the form of crystalline plates: both are obtained from coal-tar by distillation.

Cyanogen.—This substance is a gaseous compound of nitrogen and carbon—technically, a *bicarburet of nitrogen.* It burns with a purple flame, and destroys life on being breathed. Cyanogen unites with a variety of bodies, and forms many important compounds.

Boron.

The *borax* of commerce is a compound of boracic acid and soda, and is brought chiefly from Tibet and Tuscany, under the name of *tinkal.* Boracic acid is a compound of oxygen and boron, in the proportion of one atom of the latter to three of the former. Pure boron is an opaque brownish-olive powder, infusible, and not volatile at any temperature to which it has as yet been subjected. It neither dissolves in nor acts upon water. At about 600°, it takes fire, and combines with oxygen, forming

Boracic Acid.—This substance evinces the usual properties of an acid, but it is not a powerful one at ordinary temperatures. At high temperatures, however, it displaces the strongest of the other acids, and is exceedingly useful in fluxing out the baser metals from the nobler. When the acid is detached from borax, by vitriol being poured upon a strong hot solution of that compound, boracic acid exhibits itself in scaly crystals. It dissolves in rectified spirits, and if the solution be set on fire, it burns with a green flame. Borax itself, when heated, melts into a perfectly clear glass, which is the basis of some artificial gems of considerable beauty. Borax communicates its own fusible nature to other bodies; hence it is used as a flux. *Flux* is a general term made use of to denote any substance or mixture employed to assist the fusion of minerals. There are a considerable number of such bodies; the alkalies are those most generally used. Boracic acid is the only known compound of boron with oxygen. There has been no compound yet discovered of boron with either bromine or iodine, but it combines with chlorine, forming a gaseous acid, to which the name of *borochloric acid* has been given; and also with fluorine, forming

Fluoboric Acid, which exists in the gaseous state. It is colourless, has an exceedingly acid taste, and a smell similar to muriatic acid. It contains no water, but possesses a powerful affinity for that fluid, and is on that account sometimes used as a test of the presence of moisture in gases. Its specific gravity is 2·362; and it seems to consist of one atom of boron and three of fluorine.

Silicon or Silicium.

Quartz, or *Rock-crystal,* which constitutes so considerable a portion of the crust of the earth, consists essentially of a peculiar acid substance, called *silica,* or *silicic acid.* This substance is a compound of oxygen, with the element *silicon.* The latter was, till lately, supposed to be a brown powder, similar to boron; but recent researches, which are not yet completed, would lead to the belief that it is a bright white metal, somewhat similar to silver. When mixed with dry carbonate of potash, or soda, and heated far below redness, it burns vividly, at the expense of the carbonic acid; carbonic oxide is disengaged, and the residue is tinged black by carbon being deposited. By this process, silicon is converted into silica, which is a compound of one equivalent of silicon and three equivalents of oxygen. Silicic acid forms several important compounds, called *silicates,* with the fixed alkalies, and various metallic oxides. Every kind of ordinary glass is a silicate; the varieties (bottle, plate, flint, &c.) depending on the nature of the alkali or oxide, the proportions of the constituents, and the admixture of foreign matters.

Silicic acid or silica is the material most characteristic of the mineral kingdom. Imbedded in cavities in rocks, it is found in a pure condition as *rock-crystal.* With more or less of impurity, it forms jaspers, quartz rocks, flints, and sandstones; besides being a constituent of most rock-masses, such as granite and greenstone, as also clays and soils in general. It occurs in all spring-waters, especially those of the Geysers of Iceland. In the vegetable kingdom, silica is useful to such plants as wheat, enabling them to build up a more firm stem; and many of the lower animals have their outer casing or shell composed of this substance.

Silicon combines with chlorine, forming a *chloride of silicon.* This is a colourless volatile liquid, having a suffocating smell, and probably acid properties. With fluorine, silicon unites, and forms *Fluosilicic Acid,* which is a gaseous substance, transparent, colourless, and having a smell like muriatic acid. It smokes when mixed with moist air, and it is rapidly absorbed by water. Its specific gravity is 3·6.

Sulphur.

Sulphur, or brimstone, is found native in large quantity imbedded in the rocks of most volcanic districts, as on the flanks of Etna in Sicily, and Hecla in Iceland. Even volcanic ashes are more or less impregnated with sulphur. In the Sicilian mines, the sulphur is imbedded in masses of blue clay, which intermingle with it, and present an appearance as of marble. The earthy matter which thus accompanies the true sulphur veins, is separated from it by distillation when the sulphur is sublimed and condensed in proper receivers. Two varieties of this substance in a refined condition are known in commerce—namely, *roll sulphur,* prepared by pouring liquid sulphur into cylindrical wooden moulds; and *flowers of sulphur,* obtained by passing the vapour of boiling sulphur into a large cool chamber, where it rapidly condenses, and falls as a kind of *sulphur snow.*

The properties of sulphur are, that, when in mass, it is a pale, yellow, brittle solid; quite insipid and inodorous in the cold, but when heated or rubbed, acquires a peculiar odour. It is not soluble in water nor in alcohol, but is dissolved by turpentine, the fixed oils, and bisulphuret of carbon. The latter is its best solvent, and when warm, takes up about one-third its own weight of sulphur, which it deposits in greater part on cooling in the form of crystals. A roll of sulphur heated slightly, by being held in the palm of the hand, splits into pieces with a crackling noise, owing to the unequal expansion of its several parts. It is a non-conductor of electricity, and, when rubbed, becomes highly electric. It has a specific gravity of about 2. Its point of fusion is 232°; between 232° and 280° it possesses the highest degree of fluidity, is then of an amber colour, and if cast into cylindrical moulds, forms the common *roll sulphur* of commerce. It begins to thicken about 320°, and acquires a reddish tint; and at temperatures between 428° and 482° it becomes thick and highly tenacious. From 482° to its boiling-point it again becomes liquid, but never to the same extent as when at 248°. When heated to 430°, or thereby, and suddenly cooled, by being poured into water, it becomes a stringy and ductile mass, and may be used for taking impressions of seals, &c. It begins to rise slowly in vapour before it is completely fused, but at 792°, or thereby, it volatilises rapidly, its condensed fumes forming the fine powder known as the *flowers of sulphur.* Sulphur is extensively used in the arts; for instance, in the manufacture of gunpowder. With oxygen it combines in many proportions, forming compounds, all of which possess acid properties.

Sulphurous Acid.—When sulphur is heated to 300° in the open air, it takes fire, and burns with a pale-blue flame, at the same time emitting abundance of fumes of a suffocating nature, which are sulphurous acid.

A more convenient method of preparing the gas is to drench charcoal, shavings, straw, &c., with sulphuric acid, and apply heat, when sulphurous acid gas

(accompanied by carbonic acid) is evolved. Where pure gas is desired, copper or mercury should be substituted for the charcoal.

At ordinary temperatures, sulphurous acid is a colourless and transparent gas, with the peculiar and well-known odour of burning brimstone, and an acid taste. Its specific gravity is 2210. At 0° F., and surrounded by a freezing mixture of ice and salt, it becomes liquid; and placed under an air-pump in working order, and immersed in a freezing mixture of carbonic acid and ether, it becomes solid. Ordinary sulphurous acid is soluble in water to the extent of thirty times the volume of the water, producing a solution which possesses the marked odour of the gas, as likewise many other of its properties. The gas is not combustible, nor is it a supporter of combustion. To animals, it is quite irrespirable. The gas, and its solution in water, redden litmus, and possess great bleaching powers, as shewn in the rapidity with which it whitens coloured roses, red cabbage infusion, or woollen, silk, and straw goods. For the latter purposes, it is used on the large scale in the arts and manufactures. Sulphurous acid has likewise the property of arresting the decomposition of putrefying matter, and as a fumigating agent it has been used from time immemorial. It is composed of one equivalent of sulphur united with two equivalents of oxygen, and combines with bases such as soda to form a class of sulphites, of which sulphite of soda is an example.

Sulphuric Acid, or *Oil of Vitriol*, differs from the preceding acid in containing one half more oxygen. In its manufacture, two stages are observed in the process: *First*, The production of sulphurous acid, and *Second*, The oxidation of that body into sulphuric acid. The materials employed are—1. Sulphur, by the combustion of which sulphurous acid is produced; 2. Nitrate of soda, drenched with sulphuric acid to liberate the oxidising agent, nitric acid; 3. Air; and 4. Steam. The apparatus employed is a large leaden chamber, divided into compartments by lead curtains, having an oven connected with it, in which the more solid ingredients in the manufacture are placed, and a boiler to supply steam. When the gases and vapours enter the chamber, three of the sulphurous acid atoms attack the nitric acid, rob it of three of its equivalents of oxygen, convert themselves into molecules of sulphuric acid, which dissolve in the steam; whilst they leave the nitrogen of the nitric acid in combination with only two atoms of oxygen as nitric oxide. The latter substance, whenever it comes in contact with the oxygen of the air in the chamber, seizes two atoms more than it already possesses, and produces nitrous acid, which is again attacked by sulphurous acid. This process is repeated again and again, till the minute amount of nitric acid has oxidised a large amount of sulphurous acid. The oil of vitriol obtained at first has a specific gravity of 1·600, or less, and contains much water. It is concentrated by evaporation in lead basins, and subsequently in platinum retorts, when it acquires a density of 1·850. Sulphuric acid prepared in this manner is a colourless, oily liquid, which rapidly darkens in tint when dust or any carbonaceous matter gets access to the bottle. It is the acid of acids, having a most decided acid taste and action on colouring matters. It is one of the most powerfully corrosive substances known. When a bottle nearly filled with sulphuric acid is unstoppered, and exposed to the air, it absorbs moisture therefrom, the liquid increases in bulk, and ultimately runs over the side. The affinity of this acid is likewise noticed by pouring it into water, when much heat is evolved. Owing to the same property, its great affinity for, and consequent absorption of water, sulphuric acid readily chars wood, paper, and other organic substances, when these are immersed in it. The enormous quantities of this acid which are being constantly manufactured in this country for home use and exportation, have led to its being designated 'English oil of vitriol.' This variety retains one equivalent of water in combination with one of true acid. A more concentrated variety called *Nordhausen Sulphuric Acid*, prepared by heated, dry, and pulverised sulphate of iron in fire-clay retorts, from which it is distilled, contains only one of water to two equivalents of the real acid. This latter kind, when redistilled in dry vessels, yields crystals of *Anhydrous Sulphuric Acid*. The English oil of vitriol is very extensively employed by bleachers, dyers, calico-printers, &c. It forms a very numerous and important class of salts called *Sulphates*. The compounds of sulphur and oxygen—namely, the hyposulphurous and hyposulphuric acids—it is unnecessary to notice. Sulphur unites with chlorine in two proportions. It also combines with bromine, iodine, and fluorine, but its next most important combinations are those with hydrogen.

Sulphuretted Hydrogen, or *Hydrosulphuric Acid*.—This gas is present in, and is the cause of the fetid smell of rotten eggs. It is a constant accompaniment to the rotting of animal matter, being specially evolved from cesspools and sewers. It is likewise present in that class of mineral waters popularly called sulphureous. Sulphuretted hydrogen may be procured by placing sulphuret of iron, water, and sulphuric acid in a bottle with bent tubes, and collecting the gas evolved over hot water. It is colourless and transparent, with a disagreeable odour, and a sweetish taste. It is a non-supporter of combustion, and, when breathed, destroys animal life. Its specific gravity is 1175. It is combustible, and burns with a bluish-red flame. Water absorbs 2½ times its bulk of this gas; and if it be passed through water tinged with a vegetable blue, it will change the colour to red. A few drops of nitric acid let fall into a vessel filled with sulphuretted hydrogen, will set fire to it. This gas blackens silver, and the woodwork of rooms painted with white-lead are often tarnished, from human exhalations containing a portion of it. Its atomic constituents are one atom of sulphur and one atom of hydrogen.

Selenium.

This is a substance nearly allied to sulphur in its nature, although it in some respects partakes also of the character of a metal. It is associated with sulphur in its native state, and is often found in the sulphuric acid of England and the continent. It acts the same part as sulphur in mineral compounds. As prepared, selenium is a deep-red coloured powder, which becomes semi-fluid at 392°, fuses at 482°, and boils at 1292° F., evolving a vapour of a less yellow tint than that of sulphur. When heated to ignition, selenium gives off a very decided odour of horse-radish. It is a bad conductor of heat, a non-conductor of electricity, and is also non-electric. Like sulphur, it sublimes into flowers. The compounds of selenium and oxygen bear a strong analogy to some of those of oxygen with sulphur.

Phosphorus.

This substance is always found in a state of combination. It occurs to a small extent in granite and other rocks and minerals, and largely in the fossil guano called coprolites. It is likewise present in plants, especially those which are edible, and in animals of high organisation, forming one of the essential constituents of bones, blood, &c. In the preparation of phosphorus, bones are first calcined, to burn away organic matter, and the white *bone ash* left is ground to powder, and digested in dilute sulphuric acid. After subsidence, the liquid is decanted off, evaporated nearly to dryness, mixed with charcoal and sand, and heated in a fire-clay retort. The phosphorus is set free, and distils over by the neck of the retort, which, being immersed in cold water, admits of the phosphorus there condensing in pellets the size of a pea. These being collected, can readily be fused under hot water, and the liquid phosphorus so obtained run into moulds, from which, when cold, it is extracted in the form of sticks.

At ordinary temperatures, phosphorus is a solid of a

vary consistence and aspect. When newly prepared, it is soft, flexible, and translucent; but age makes it hard, brittle, and opaque. Its specific gravity is 1·770. Raised to a temperature of 108° F., it melts into a clear amber-coloured liquid: and at 550° it boils, giving off a vapour of the great density of 4350. In cooling, if kept at rest, phosphorus will remain liquid even at 40° F.; but the moment it is agitated, the whole is frozen. It is not soluble in water, but dissolves to a greater or less extent in alcohol, ether, fixed and volatile oils, as also in bisulphuret of carbon. The latter is its best solvent, as it takes up one-fifth of its own weight of phosphorus. Exposed to the air, uncovered by water, phosphorus emits an odour of garlic, and becomes luminous from a slow combustion or oxidation proceeding. Heat is thus evolved, and in a short time the mass fuses, and ultimately takes fire spontaneously, and burns with a vivid light. This combustion of phosphorus reaches a dazzling brilliancy when pure oxygen is the atmosphere in which it is burned.

Red Phosphorus, or *Amorphous Phosphorus*, is procured from ordinary phosphorus by enclosing dried chips of the latter in a vessel with little access to air, and kept for days at a temperature of about 440°. The amber-coloured liquid slowly changes into the same weight of a red powder. Should the temperature be raised to 482°, the red variety again returns to the state of ordinary phosphorus. The tint of the coloured variety is not constant, but ranges from a scarlet to a blackish brown. It has a specific gravity of 2·089 to 2·106; is insoluble in water, alcohol, ether, and bisulphuret of carbon; is not luminous in the dark; does not oxidate at ordinary temperatures, and therefore need not be kept under water, but burns when heated to 482°. The most remarkable difference between red and ordinary lies in the poisonous character of that in common use, and the *non*-poisonous property belonging to the red variety.

Phosphoric Acid is the substance produced during the combustion of phosphorus in air or pure oxygen. It may likewise be formed by acting on bone-ash (in greater part a compound of phosphoric acid and lime) by dilute sulphuric acid, which combines with the lime to form the comparatively insoluble sulphate of lime, whilst the phosphoric acid remains in solution. It is readily soluble in water, and forms a colourless and odourless liquid, possessing the usual characters of an acid. It has a sour taste, with a powerful corrosive action on the teeth, but little on animal and vegetable tissue in general. It neutralises bases such as lime, and forms three series of salts: 1. With one atom of base; 2. Two atoms of base; and 3. Three atoms of base. The proportions in which the constituents are present in the phosphoric acid is, one equivalent of phosphorus to five equivalents of oxygen. There are other compounds of phosphorus and oxygen containing less oxygen than phosphoric acid does, but these are not of much importance.

Phosphuretted Hydrogen, *Ignes Fatui*, *Will-o'-the-wisp*, or *Jack-o'-lantern*, is naturally emitted from boggy places and grave-yards, and has been long known and feared for its phantom appearance. It may be prepared by placing in a retort some hot water, a piece of phosphorus, and a little potash. Heat should be at once applied to the bulb, and the extremity of the neck of the retort plunged underneath a stratum of water. The gas immediately begins to come off, continues to explode with the air in the retort till that is exhausted, chases the spent gases out, and then gurgling through the water of the receiving-basin, bursts spontaneously into full flame when it escapes into the atmosphere. Phosphuretted hydrogen is a colourless gas, with a garlic smell, and a bitter taste. When mixed with oxygen, *rarefaction* causes them to explode, as *condensation* produces explosion in other gases—a very remarkable property of this substance. This gas may be detonated also with protoxide and deutoxide of nitrogen. When mixed with chlorine gas, it burns with a greenish-yellow flame. It is composed of equal volumes of hydrogen and phosphorus vapour. There are other compounds formed of these two substances: phosphorus combines also with chlorine, bromine, and iodine, in two proportions each; and unites with fluorine, carbon, sulphur, and selenium.

Chlorine.

The principal source of chlorine is common salt (a compound of chlorine and sodium), which occurs largely in many parts of the world as a rocky mass, called *rock-salt*, as also dissolved in the ocean and many spring-waters.

The most convenient method of preparing chlorine gas is to introduce into a retort, or flask with bent tube, some hydrochloric acid, with a little powdered peroxide of manganese, and apply heat. The gas readily comes away, and may be collected in the ordinary way at the pneumatic trough, or by allowing the gas to descend into dry bottles (fig. 14). A more economical process, and one

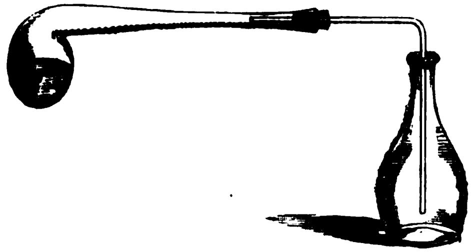


Fig. 14.

followed on the large scale, is to employ eight parts of common salt, six parts of peroxide of manganese, and thirteen parts of oil of vitriol. A complicated reaction ensues, and chlorine is given off.

The properties of the gas are, that it has a yellowish-green colour, a powerful suffocating odour, and a strong astringent taste. It is not combustible, and is only a partial supporter of combustion, as shewn by placing a lighted candle in the gas, when the hydrogen of the candle alone burns, and sets free the carbon as smoke or soot. Many metals, however, such as copper, antimony, arsenic, Dutch leaf, &c., in thin leaves or fine division, burn readily when introduced into chlorine, and combine with it, forming *chlorides*. An atmosphere containing much of this gas cannot be inspired without dangerous effects on the animal system; but when a very small quantity is present, as in the vicinity of bleaching-works, it becomes rather pleasant. It has a specific gravity of 2470, and has been liquefied under the

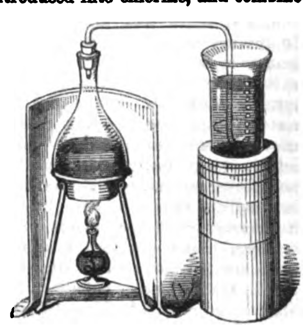


Fig. 15.

combined effects of cold and pressure. It is readily soluble in water (fig. 15), and then yields *chlorine water*, which possesses the same colour, odour, and taste as the gas itself. Both the gas and its solution in water possess the power of destroying all vegetable colours, and of rendering vegetable bodies exposed to their action white. This property has occasioned the introduction of chlorine, combined with lime, into bleaching; for if unbleached linens or cottons be exposed to its action, the matter which gives them their gray colour is destroyed, and the substance assumes a brilliant whiteness. Chlorine, however, must be used cautiously; for if applied in its pure,

and not sufficiently diluted state, it destroys the fibre of the cloth. It is also used in fumigation, being destructive of effluvia and infectious matters arising from putrefaction, disease, &c. Chlorine combines with oxygen in four different proportions: two of them contain so much oxygen as to form acids; these are chloric acid and perchloric acid; but as the other two do not manifest any acid properties, they are to be considered as oxides, and are called protoxide of chlorine and peroxide of chlorine. Besides uniting with oxygen, chlorine combines with hydrogen, and forms the well-known acid called

Muriatic or *Hydrochloric Acid.*—If chlorine and hydrogen be mixed together in equal volumes, and exposed to common daylight in a glass flask, they will in a little time combine, and even explode in combining if exposed to sunlight or the light of a candle. Hydrochloric acid gas may be more readily prepared, by placing in a retort equal weights of common salt and sulphuric acid, and applying heat. The gas is quickly evolved, and may be received in jars at the mercury trough, or in dry bottles. Its specific gravity is 1269. In its pure state, this gas is transparent, colourless, and elastic; under very strong pressure it condenses into a liquid. Water absorbs this gas with such avidity that one cubic inch absorbs 418 cubic inches of the gas, and forms the ordinary hydrochloric or muriatic acid. With these proportions of constituents, its specific gravity is 1210; one hundred grains of it consist of 42 of real acid, and 58 of water. It is a colourless liquid; and when exposed to the air, it smokes, because the gas exhaled condenses the moisture of the atmosphere. It extinguishes both flame and life, and is not inflammable. It has a pungent, suffocating, and somewhat aromatic smell, and powerfully reddens vegetable blues. An immense number of salts are formed from the combination of hydrochloric acid with oxides: such as common sea-salt, which is a muriate of soda, or chloride of sodium. These are very extensively used, both in the arts and medicine. Chlorine combines with nitrogen, and forms what is called

Chloride of Nitrogen.—This is an oily liquid, and the most powerfully explosive compound known. It consists of four volumes of chlorine combined with one of nitrogen.

Bromine.

Bromine is usually extracted from *bittern*—that is, the uncrystallisable residue left after chloride of sodium (common salt) has been extracted from sea-water. It appears to be an essential ingredient of the saline matter of the ocean, and is found in all its waters, as well as in most of the plants and animals which inhabit them. It occurs also in many springs. It resembles chlorine in many of its habitudes; at common temperatures, it is a liquid of a brownish-red colour, very disagreeable smell, sharp, strong taste, powerfully corrosive of organic bodies; and when taken internally, a violent poison. Its specific gravity is 2·976; it destroys vegetable colours almost as powerfully as chlorine. Like chlorine, it sets fire to certain metals when brought into contact with it; it is not combustible, and it extinguishes combustion; it becomes solid at a little below zero; but if combined with water, so as to form a hydrate, it affords fine red crystals at 32°.

An acid is formed by the combination of bromine with oxygen, and is called bromic acid; another with hydrogen is called hydrobromic acid.

Iodine.

This substance is derivable from sea-plants, and in some of its properties much resembles chlorine, which is also a marine production. It occurs in sea-water and many spring and river waters, some minerals, the majority of sea-weeds and land-plants, as also in marine and land animals. It is generally prepared from sea-weeds, which are collected, dried on the beach, burned, and the ashes treated with water, which dissolves out the compound of iodine. The solution so obtained is placed in a retort, treated with sulphuric acid and binoxide of manganese, and heat applied. The iodine sublimes, and is deposited in the cool receiver in the form of small bluish-black scaly crystals with a metallic lustre. These can readily be purified by resublimation. Iodine has a specific gravity of 4·948, fuses at 225°, and boils at 347°, when it rapidly volatilises as a splendid violet-coloured gas, with the high density of 8716. In the crystalline condition, it is very sparingly soluble in water, but is readily dissolved by alcohol, ether, alkaline iodides, and water containing a few iron filings. Its smell is disagreeable, its taste acrid and hot, and it possesses poisonous properties. It is a powerful stimulant, and has been employed as a medicine. It destroys vegetable colours, but not so completely as chlorine. It forms a beautiful blue colour when mingled with water holding starch in solution. Iodine combines with oxygen, forming iodic acid. A compound of iodine and nitrogen is exceedingly explosive.

Fluorine.

The existence of this substance, strange to say, is conjectural; yet its separate identity is supported by the strongest analogies. It exists in fluor, or Derbyshire spar, and is thus called fluorine. If some of this mineral in powder be distilled with strong sulphuric acid, from a leaden retort into a leaden receiver, kept cold with ice, an intensely active fluid is produced. 'It has,' says Davy, 'the appearance of sulphuric acid, but it is much more volatile. When applied to the skin, it instantly disorganises it, and produces very painful wounds. When it is dropped into water, a hissing noise is produced, with much heat, and an acid fluid is formed.' This substance has been called *hydrofluoric acid*, because it is conjectured to have fluorine as a base, combined with hydrogen, to form an acid, upon the principle which we have formerly described. The diluted solution, or the vapour of hydrofluoric acid, acts energetically on glass, and is employed for the purpose of *etching* on this material. (See No. 21.)

II. METALLIC ELEMENTS.

Metals of the Alkalies.

Potassium is the metal present in that well-known and very useful article potash. The properties of potassium were first determined by Davy in 1807, to whom we are indebted for the discovery of the composition of the alkaline bodies. It is a white metal, like silver, with a shade of blue. At 32° it is hard and brittle, at 50° is soft and malleable, at 136° melts, and at a low red heat evaporates. Its specific gravity at 60° is ·865, being lighter than water. When exposed to the air, it rapidly absorbs oxygen, and forms potash. This latter body, as found in commerce, is always combined with water, which cannot be expelled by heat. When potassium is thrown on the surface of water, upon which it swims, it decomposes that fluid with such rapidity that the metal takes fire, and burns (along with the hydrogen evolved) with a violet-tinted flame. The protohydrate of potassa, which is solid at common temperatures, is employed in surgery as a caustic, under the name of *potassa fusa:* it destroys all animal textures.

Sodium is a metal so similar in most respects to the foregoing, as to stand in no need of particular description. It is the metal present in the alkali called soda, which is formed when the metal is brought into contact with water, or when it is heated in oxygen. Sodium decomposes water, and in its relations to other bodies bears a strong resemblance to potassium. The uses of soda are well known, as are those of common salt, which is chloride of sodium. Sulphuret of sodium was lately discovered to be the colouring principle of the *lapis lazuli*, and since then has been used in the preparation of artificial ultramarine, the finer specimens of which are quite equal to the natural product, and much less

expensive. Sodium, which was discovered after potassium in 1807, is called *Natrium* by the German chemists.

Lithium is the metal of the alkali called lithia, which is of a white colour, and has a taste fully as caustic as that of potash itself. It is of course an oxide of lithium.

Metals of the Alkaline Earths.

Barium is the metal found in *barytes* or *heavy spar*, an alkaline earth, which is so named from its great density; *barys*, heavy. It is of a yellow appearance, absorbing oxygen rapidly by exposure to the air, thus forming barytes; and it also rapidly decomposes water.

Strontium.—This metal is present in strontia, an earth very similar to the foregoing. Strontium and barium, both discovered by Davy, resemble each other very much in most of their properties, and their combinations with oxygen have also a very strong resemblance. Strontium was originally extracted from strontianite, native carbonate of strontia, a mineral found at Strontian, in Scotland; hence the name *strontites*, or *strontia*.

Calcium is the basis of the well-known and indispensable commodity lime. *Lime* (*calx*) has been known from the remotest ages, and appears always in combination with an acid, most commonly with the carbonic, constituting *limestone*, *marble*, *calcareous spar*, *chalk*, and frequently with sulphuric acid, constituting *gypsum*, *selenite*, and *sulphate of lime*. It combines also with various other acids. Calcium is yellow, like gold, solid, and much heavier than water. When heated in the open air, it burns brilliantly, and quicklime is produced. Calcium unites with oxygen in two proportions, forming lime and peroxide of calcium. Pure lime has an acrid taste, and is sparingly soluble in water. It, however, readily absorbs water poured upon it, and swells, producing at the same time a great heat. The fact is, that the water becomes solidified, and of course gives out a great quantity of heat, which partly accounts for the rise of the temperature. This process is called slaking lime. Lime combines with chlorine, and forms *chloride of lime*—a substance which has become an important article of commerce, under the name of *bleaching-powder*. It is a white powder, with a hot taste, having the power of destroying vegetable colours.

Magnesium.—This metal is the basis of magnesia, a substance universally known from its frequent employment in medicine. Magnesium is obtained by the electrolytic decomposition of chloride of magnesium; and in common with barium, calcium, and strontium, it has been lately isolated, and its properties determined, by Dr Matthiessen of Heidelberg. It burns with a red light, and combining with oxygen, becomes *magnesia*. This is a soft, elastic, tasteless powder, not sensibly soluble in water, and slowly changing vegetable blues to green.

Metals of the Earths.

This family comprehends five substances, the oxides of which are white tasteless powders, distinguished by the name of *earths*.

Aluminum.—Alumina, which, when pure, is a fine light powder of brilliant whiteness, is an essential constituent in every kind of clay, and constitutes the base of *alum*, from which substance it may easily be obtained. It is a compound of oxygen and aluminum, consisting of two parts of the former to three of the latter. This metal, when burnished, assumes a metallic lustre resembling that of tin. It is not easily fused; but at a red heat it burns with great splendour, and is converted into alumina. This substance, so useful in the manufacture of every species of pottery, is the only compound known of oxygen with aluminum. Alumina possesses the remarkable property of shrinking into less bulk, according to the intensity of the heat which is applied to it; hence it was employed by Wedgewood as a kind of thermometer, or rather *pyrometer*, for measuring very high degrees of temperature, in furnaces for instance. A gauge is used for measuring the amount of the contraction.

Beryllium, or *Glucinium.*—Berylla, which is the oxide of beryllium, exists to about 14 per cent. in the beryl or emerald, from which it can be extracted. Beryllium is a dark-gray powder, which, when burnished, acquires the metallic lustre.

Yttrium.—Yttria, which constitutes the oxide of this metal, is obtained from a scarce mineral called *gadolinite*, found at Ytterby, in Sweden. Yttrium is procured from it in iron-gray scales. Mosander asserts the existence of two closely allied metals, which he calls *Erbium* and *Terbium*, also from Ytterby.

Zirconium.—The earth called zirconia is a harsh whitish powder, destitute of taste or smell. Zirconium is obtained in brilliant scales, which, when burnished, acquire the metallic lustre. Svanberg's experiments have rendered probable the existence of a closely allied metal, which he calls *Norium*.

Thorium, is a metal of a leaden-gray colour, heavy, and, under the burnisher, shews metallic lustre.

Chromium is a metal of a whitish colour and brittle consistency. Its specific gravity is 5·900. It is only obtained pure in small grains. Chromium combines with two proportions of oxygen, forming two compounds, the *green oxide* and *chromic acid*. It is used in coloured glass-making, and glass and porcelain painting. It is also employed in enamelling, and as a pigment. To glass and enamel it communicates a green colour, but to the painter it affords one of his prettiest yellows. Chrome red is the bichromate of potassa, and chrome yellow is the chromate of lead.

Metals Proper.

Iron.—This well-known substance is one of the seven metals with which the ancients were acquainted; these were gold, silver, copper, iron, tin, lead, and mercury. Iron is a metal of great utility, and it is fortunately found abundantly. Almost every mineral contains it. The ore from which the iron of Great Britain is chiefly obtained is a *carbonate of iron*. Iron, after passing through a fiery ordeal, has a grayish colour, a metallic lustre, and when burnished, a good deal of brilliancy. Its hardness exceeds that of most metals; and when in the state of steel, it may be rendered harder than most bodies. Its specific gravity is 7·843 after hammering. It is attracted by the magnet, and may itself be converted into a permanent magnet. It is malleable at every temperature, very ductile, and very combustible, for we see a thin wire burn in the flame of a common candle. It burns brilliantly in oxygen, with which it combines in two proportions, forming oxides, or *rusts*. The most important of its combinations with simple substances are those with carbon, which form the important compounds *cast iron*, *steel*, and *plumbago*. Iron forms with the acids a numerous and valuable class of salts. (See METALLURGY.)

Manganese.—When this substance is pure, which is rarely the case, it is rather whiter than cast iron, of a granular texture, and may be reduced to powder by pounding. Its specific gravity is 8·013. It is attracted by the magnet, only at a very low temperature. It gradually absorbs oxygen from the atmosphere, and decomposes water, a property which it loses when alloyed with iron. It is much in use. Glass-makers use it for two purposes; first, for communicating a purple or violet colour, or for destroying all colour, and rendering the glass colourless. Manganese has a strong affinity for oxygen, with which it combines in seven proportions, forming acids and oxides.

Nickel.—This metal, when pure, has a white colour, like silver; is rather softer than iron; is malleable both hot and cold; is attracted by the magnet; and, like iron, can be converted into one. Its specific gravity is 8·380 after fusion. The preparations of this metal contain poisonous qualities. Nickel combines readily with oxygen, forming two oxides. Nickel is chiefly derived from a copper-coloured mineral found in Westphalia, called

kupfernickel; nickel being an epithet of detraction, because the ore looked like copper, and yet none could be extracted from it. Nickel is a principal ingredient in the alloy called German silver.

Cobalt.—This metal has a gray colour, with a shade of red, and is not brilliant. Its texture is granular; it is rather soft and brittle; its specific gravity is 8·700. It is used for giving a blue colour to glass and porcelain; the tint is beautiful, and hence the metal bears a high price. It unites with oxygen, and forms two oxides; these are the preparations of cobalt used in the arts. Its name is derived from *kobold*, an evil spirit, because the German miners, at a time when they were ignorant of its value, considered it unfavourable to the presence of more valuable metals.

Zinc.—This metal is of a bluish-white colour, and is composed of plates adhering together. It is a hard metal, being acted on by the file with difficulty; and after fusion, its specific gravity is 6·896. It becomes malleable at 212°, and melts at 773°, or before it is quite red. When heated red-hot with access of air, it takes fire, burns with an exceedingly beautiful greenish or bluish-white flame, and is at the same time converted into the only oxide of zinc with which we are acquainted. It is of a snow-white colour, is tasteless, and insoluble in water. With copper, zinc forms that well-known and useful alloy called *brass.*

Cadmium.—This metal, which is commonly associated with the ores of zinc, has a white colour, with a shade of bluish-gray, and resembles tin in its appearance. It is very malleable, and has a specific gravity after fusion of 8·604.

Tin possesses a fine white colour, and has a good deal of brilliancy. Its specific gravity after fusion is 7·285. It is very malleable. Tin-leaf, or *tinfoil*, as it is called, is about the one-thousandth part of an inch thick, and it might be made much thinner if requisite. It is ductile, but of inferior tenacity. It is very flexible, and produces a remarkable crackling noise when bended. It melts at 442°; but a very violent heat is required before it will volatilise. It slowly tarnishes with the air, and when intensely heated, oxygen being supplied, it burns with great brilliancy. Tin combines with oxygen in three proportions, forming the protoxide, which is *black*, the sesquioxide, which is *grayish*, and the peroxide, which is *yellow*. It alloys with various metals. It is used in coating vessels, either in a pure state or alloyed. Pewter is composed of lead and tin; the latter rendering the former, a poisonous metal, quite innocuous.

Arsenic.—The *white arsenic* of commerce is a combination of this metal and oxygen. When mixed with *black flux* (cream of tartar, heated to redness in a covered crucible), and subjected to heat, it is reduced to the metallic state. It has a bluish-white colour, is soft, brittle, and easily reduced to fine powder. Its specific gravity is 5·672. When moderately heated, it volatilises, combining with oxygen, and forming the arsenic of commerce, so well known for its destructiveness to animal life. With oxygen, arsenic forms two acids—the *arsenious* and *arsenic*. *Arsenious acid* is a white, brittle, compact substance, having a weak, acrid taste, which at last leaves an impression of sweetness. It is one of the most virulent poisons known. *Arsenic acid* is quite similar in its constitution to phosphoric acid.

Antimony, which was discovered by Basil Valentine in 1490, possesses, when pure, a white colour, with a shade of blue. Its texture is fibrous, and it is easily reduced to powder by being pounded in a mortar. Its specific gravity is 6·800. It melts when heated nearly to redness, and at a higher heat it is sublimated in white fumes. It combines with oxygen in three proportions, and forms three compounds, two of which possess acid properties. The other is an oxide, which constitutes the base of all the active medicinal preparations of this metal. With chlorine it combines in two proportions, forming two chlorides, which are analogous to two of the compounds formed with oxygen. Antimony is extensively used in the arts, particularly in typefounding, stereotyping, and the manufacture of the white-metal utensils now so generally used as substitutes for silver.

Tellurium is a metal, having a silver-white colour, and considerable brilliancy. *Vanadium* is a whitish metal resembling silver, brittle, and is easily dissolved in nitric acid. *Uranium* is a metal of a white colour, of considerable lustre, and when heated to redness, takes fire. It produces a deep-green protoxide, which gives a black colour to porcelain, and a fawn-coloured peroxide, which communicates to porcelain an orange colour. Its specific gravity is 9·000. *Molybdenum* has a silvery white colour, is brittle, and has a specific gravity of 8·6. *Tungsten* is of a grayish-white colour, is very hard and heavy, having a specific gravity of 17·6. *Columbium*, when burnished, assumes a yellowish-white colour and a metallic lustre. *Titanium* has a white colour, and considerable brilliancy. *Cerium* exists in a reddish-coloured mineral found in Sweden, called *cerite*. *Lantanium* and *Didymium* may also be ranked under this family.

Lead.—This is one of the most abundant of all the metals, and one of the softest and most fusible. Lead has a bluish-white colour, and a good deal of lustre; but it soon tarnishes. Its specific gravity after fusion, which takes place at 606°, is 11·45. Lead is very malleable; it is also ductile, but its wire possesses little tenacity. By exposure to a very strong heat, it is volatilised, and at the heat of burning hydrogen, urged by oxygen, it burns with a bluish flame. While exposed to the atmosphere during fusion, it imbibes oxygen, and is converted into an oxide. There are three oxides of lead—the protoxide, which is known in commerce and the arts as a yellow paint, under the name *massicot*, or, if it be semi-vitrified, *litharge;* the deutoxide is also a paint of a brilliant red colour, inclining to orange—it obtains the name of *minium*, or *red-lead;* and the peroxide, which is of a deep puce *brown* colour. Lead is rendered hard by antimony; and the alloy mixed with a little tin, constitutes the material from which printers' types are elaborated. The salts of lead are numerous, and very important. *White-lead*, or *ceruse*, the only white used in all oil-paintings, is made by subjecting thin plates of lead, rolled up spirally, to the fumes of vinegar, and afterwards to carbonic acid exhalations. The lead soon becomes corroded, and assumes a white appearance and a brittle consistency. If this substance be dissolved in acetic acid, or vinegar, it becomes *sugar of lead*. Lead is never found native; by far the most common state in which it occurs is sulphuret of lead, or *galena*.

Copper, in point of general utility, ranks next to iron. It possesses a red colour, and a great degree of brilliancy. Its specific gravity, after being rolled out into plates, is 8·960. It has great malleability, and very considerable ductility. A bar of cast copper, one quarter of an inch thick, requires 1192 pounds to break it, whilst hammered copper requires nearly 1000 pounds more to break it. It melts at 1996°; and if the heat be increased, it evaporates in fumes, which are visible. When rubbed, it emits a smell. When heated in a hydrogen flame urged by oxygen, it burns brilliantly, emitting a dazzling green light; a piece of copper in a coal-fire tinges the blaze green. When exposed to air and moisture, it changes into a green carbonate of copper on the surface. With oxygen it combines in three proportions, forming three oxides, two of which occur native; the other is not a permanent compound. Its alloys with tin are very important, forming *bronze, bell-metal*, and other alloys.

Bismuth has a reddish-white colour, and is composed of broad plates adhering to each other. It is one of the most fusible of the metals, melting at 476°; it communicates its fusibility to other metals; hence its use as a *flux* and *solder*. Its specific gravity is 9·9. Although

not very brittle, it is not malleable, unless when heated, nor can it be drawn into wire. A mixture of tin, lead, and bismuth is so fusible that it melts when thrown into boiling water. A toy of this kind is well known; it is a spoon, which, when immersed in a very hot liquid, immediately melts. What is called Newton's fusible metal, is a compound of eight parts by weight of bismuth, five of lead, and three of tin; it melts at 212°. The nitrate of bismuth furnishes the medicinal powder called *pearl white* when it is thrown into water.

Mercury, or *Quicksilver*.—This metal has a silver-white colour, possesses great brilliancy, and remains fluid at the common temperature of the atmosphere. Its specific gravity at 60° is 13·59; at 39° below zero, when it assumes the solid form, it is 14·. When solid, it may be beaten out with a hammer, or cut with a knife. When heated to 662°, it boils; and when heated in the open air, it oxidises. The oxides and chlorides of mercury afford an admirable proof of the truth of the atomic theory. The alloys which mercury forms with the other metals are usually termed amalgams. This metal occurs in South America, California, and in Spain, in great abundance; but the mine of Idria, in Carniola, is perhaps the greatest in the world, and has been wrought for more than three centuries.

Silver.—This metal is of a fine white colour, with a slight shade of yellow. When polished, it displays a great deal of brilliancy and beauty. It is very malleable, and may be beaten out into leaves so thin as 1-100,000th of an inch. It is softer than copper, and harder than gold; but its tenacity is inferior to the former metal. When melted and cooled slowly, its specific gravity is 10·5; when hammered and rolled, it is a little higher. Its melting-point is 1873°; and if it be kept melted for a long time, it absorbs oxygen; but possesses the very singular property of parting with the oxygen on solidifying. The presence of a little copper deprives it of this property. Silver forms with oxygen only one well-known oxide. It also unites with chlorine, bromine, sulphur, arsenic, &c. There are numerous alloys of silver, but few of much consequence. Silver is found in all parts of the world, sometimes associated with a variety of other metals and substances as an ore, and sometimes in the native state.

Gold, the most valuable of all the metals, always occurs in nature in the metallic state, although seldom pure. It has a beautiful yellow colour, and considerable lustre, which it retains, not being liable to be tarnished by exposure to the air. It is rather softer than silver, and after fusion it has a specific gravity of 19·5. It is the most malleable of metals, and may be beaten out into leaves no thicker than 1-282,000th of an inch; and the goldleaf with which silver wire is covered is only one-twelfth of that thickness. Its tenacity is considerable, but inferior to that of silver. It melts at 2016°. It is insoluble in sulphuric, nitric, and hydrochloric acid; but it readily dissolves in aqua regia, which is a compound of the two latter. It is difficult to oxidise gold, and still more to burn it; but both can be accomplished. Oxygen combines with gold in two proportions, forming oxides. There are a number of alloys of gold; the standard gold coin of the realm is an alloy of eleven parts of gold to one of copper.

Platinum.—This metal is white, like silver. Its specific gravity is 21·5, and its hardness is intermediate between copper and iron. It is very ductile and malleable, though much less so than gold. Its tenacity is considerable. It will not melt in the heat of our most powerful furnaces, but it may be fused by the oxyhydrogen blow-pipe. On this account, as well as its property of resisting the action of most chemical agents, it has been employed in the formation of vessels which it is necessary to subject to an extraordinary degree of heat. Like gold, it resists the action of all the single acids, but dissolves in aqua regia. There is a form of this metal which possesses extraordinary properties; it is called *spongy platinum*. It is prepared by dissolving platinum in a mixture of nitric and hydrochloric acids by heat; chloride of ammonium is added, when a precipitate falls, which must be filtered and dried. If a jet of hydrogen, from a tube of a very slender bore, be directed on this powder from a little distance, the metal immediately becomes red-hot, and it sets fire to the hydrogen. This may be repeated a great number of times.

Palladium, Rhodium, Iridium, Osmium, and Ruthenium.—These five metals occur in the platinum of commerce. They are procurable in very small quantities.

Such is a brief sketch of the sixty-two simple substances whose numerous combinations give rise to the infinite variety of objects which are found ready formed in the laboratory of nature, or have been discovered in that of the philosopher. The minerals and metals of commerce will be further treated under the heads MINING and METALLURGY.

ORGANIC CHEMISTRY.

Vitality enables plants and animals to absorb and assimilate food, consisting of the elements necessary for their increase, and also to reproduce beings of their own kind, by means of certain organs; hence they are said to be *organised*, and the substances of which they are composed are known by the general name of *organic matter*. Earths, minerals, metals, and the like, not possessing vitality, have no organs, and consist only of *inorganic matter*. Organic chemistry—in contradistinction to Inorganic chemistry—is therefore that department of the science which treats of the composition, properties, and uses, as well as of the origin, of all substances produced in the animal and vegetable kingdoms, and of the artificial compounds arising from their decomposition. The chemist finds, however, so far as the ultimate analysis of organic substances can shew, that plants and animals are composed of the same elements as inorganic matter; and that the two branches of the science are not essentially different, so far as the nature of these elements is concerned. There is this peculiarity, however, that a certain class of organic compounds possess the property of uniting with the elements, and of forming with them new combinations, which are analogous in their properties to the combinations of two simple bodies. Such compounds are called 'compound radicals;' hence the term *chemistry of compound radicals*.

VEGETABLE COMPOUNDS.

Notwithstanding the infinite diversity of form which vegetable substances assume, it has been proved that they are all mainly composed of the same elements, and these are only *four* in number—namely, oxygen, hydrogen, carbon, and nitrogen. These, again, by uniting amongst themselves, form many of the compounds which constitute the vegetable structure; and these compounds being the more immediate objects of sense in the investigation of any organisation, are called their *proximate principles*. Existing ready formed in roots, woods, barks, leaves, flowers, fruits, and seeds, we find a considerable number of proximate principles, in the form of acids, alkalies, sweet principles, bitter principles, oils, exudations; some poisonous, others wholesome; some spontaneously separating, others remaining obstinately combined. We shall give a brief outline of these, referring for further details to VEGETABLE PHYSIOLOGY, AGRICULTURE, ALIMENTARY SUBSTANCES, AND MEDICINE.

Common *Citric Acid* exists in the juice of lemons, and when crystallised, one hundred grains consist of—water 23⅝, and pure acid 76⅜, which is a compound of 42·1 oxygen, 31·58 carbon, and 2·63 hydrogen. *Malic acid* is

the sour principle of apples and other fruits. It consists of the same ingredients as the former. *Tartaric acid* is the sour principle of grapes; when a large quantity of which is left to ferment, the result, it is well known, is wine. On the side of the vessel containing this liquor, crystals of the acid, combined with potash, are formed, and these, when purified, are *cream of tartar*. Twelve parts in the 100 are water; and the remaining 88 consist of oxygen 52·97, carbon 32·39, and hydrogen 2·64 parts. *Oxalic acid.*—The plant called sorrel is valued for its acidulous taste, which is conferred upon it by this acid. It has no hydrogen in its composition, consisting merely of oxygen and carbon. It is an active poison, and, from resembling Epsom salts in appearance, many persons have fallen victims to its virulence. The antidote is powdered chalk. *Gallic acid* is obtained from nut-galls. Its most remarkable property is that of changing the colour of solutions containing iron to an intense blue-black colour, as in the case of common writing-ink. One hundred grains consist of 56·25 carbon, 37·5 oxygen, and 6·25 hydrogen. *Prussic* or *Hydrocyanic acid*, found in various fruits and flowers, is a most powerful poison. It is formed of hydrogen and cyanogen, a noxious inflammable gas. Such acids as those just described exist ready formed in fruits, &c.; they are simple *educts*. But there are others formed by chemical changes produced on certain elements contained in vegetables, which afford the base of the acid; these are acid *products;* some are produced by the agency of heat, others by the action of nitric acid. *Acetic acid*, or vinegar, is one of these, being a product of any liquid capable of undergoing the vinous fermentation. Fermentation produces alcohol, and alcohol, by oxidation, is converted into acetic acid. Several acids, when distilled at a high temperature, undergo decomposition, and new acids are formed. Their names remain the same, or have the word *pyro* prefixed, as *pyrocitric acid*, *pyroligneous acid*, &c.

It has also been ascertained that *alkalies*, as well as acids, exist ready formed in plants as one of their constituent principles. Those which evince alkaline properties of a weak character are entitled *alkaloids*. The alkalies are, *quina* and *cinchona*, which resemble each other, have a bitter taste, and neutralise acids; *morphia*, which is obtained from opium, and is a white crystalline powder; *strychnia*, one of the most powerful bitters and poisons, which has of late been much used in medicine, and as a poison; *brucia*, also a violent poison; *digitalia*, which is procured from the leaves of foxglove; *hyoscyamia*, *atropia*, *veratria*, *emetina*, &c., which are derived from henbane, deadly nightshade, &c.

Of the other proximate principles, the first deserving of notice is the woody fibre which constitutes the solid basis of all vegetable structures. It is called *lignin*, from *lignum*, wood; and consists of 52 carbon, and 48 of oxygen and hydrogen, in the ratio which forms water. With lignin are associated various other bodies, such as *resins*, which are various and abundant. In the different species of the pine-tree we discover that peculiar liquid resin called *turpentine*. From resins are obtained what are called *essential oils;* because, after the resin has been heated in a distilling apparatus, an odoriferous oil distils over, and leaves the resin hard, dark, and odourless. The *essence* of the substance is supposed to have passed away in the aëriform state—hence the name. From its speedily evaporating on being exposed to the air, it is also called *volatile oil*. The seeds of plants yield another oil, which, not evaporating, is called *fixed oil*. (See CHEMISTRY APPLIED TO THE ARTS). *Gum*—for instance gum-arabic—has the following properties: namely, transparency, tastelessness, perfect solubility in water, viscidity of the solution, capability of cementing fragments, and of affording a varnish, and total insolubility in spirit of wine. There is a class of bodies called *gum resins*, whose properties are intermediate between those of gum and resin; and somewhat allied to resins, although essentially different in most of their properties, are the substances *caoutchouc* and *gutta-percha*. They are the exuded juices of peculiar trees, and are composed of carbon and hydrogen.

From wheaten flour a substance is obtained called *gluten*, from its glutinous nature. A substance called *vegetable albumen* seems to be the basis of all emulsive grains in place of starch, and greatly resembles it. *Starch* is a fine white sediment, capable of being extracted from the white and brittle parts of vegetables, particularly the tuberose roots and the seeds of the gramineous plants. One of the most remarkable properties of starch, or, as it is called, *fecula*, is that of being convertible into sugar by the action of diluted sulphuric acid. Every one, we suppose, should know what *sugar* is; being in particular a sweetener of the kindly beverages tea and coffee. It is derived from many sources—from the sugar-cane, maple-tree, beetroot, and grapes. Nothing is easier than its formation from grapes: grape-juice is to be saturated with chalk, clarified with white of eggs, or blood, and evaporated; after a few days it assumes the form of a crystalline mass. *Tannin.*—From oak-bark, or nut-galls, a peculiar substance is obtained, called tannin—so named from being the material employed in tanning leather. It is inodorous, colourless, and possesses a rough astringent bitter taste.

ANIMAL COMPOUNDS.

The chief substances which enter into the composition of animal matter are oxygen, hydrogen, nitrogen, carbon, phosphorus, and lime. We also find certain acids and metals, but in quantity so minute, as not to affect the truth of the general statement.

Bone consists principally of phosphate and carbonate of lime and *gelatine*. The latter is the coagulating, or rather elastic principle in all *animal jellies*. When bones are burned in a close vessel, they form *ivory black*. *Fibrin* is obtained from the animal tissue, and when recently obtained, it is elastic; but when perfectly dry, it is somewhat horny and transparent. The *tendons*, *ligaments*, and *membranes*, are nearly allied to gelatine in their nature. *Fatty* substances, as lard and oils, are formed chiefly of carbon, with a little hydrogen and oxygen—one or both. *Albumen* is a substance very abundant in animal matter. It occurs nearly pure in the white of eggs. Of this substance in the coagulated state, along with gelatine, are *horns*, *nails*, and *hoofs* composed.

Of the fluids of the animal body, *blood*, one of the most important, is viscid, of a red colour, exhaling a vapour of a peculiar odour. When left at rest a few hours, its appearance is very much altered, having separated into two parts—one quite liquid, of a whey-like colour, and called *serum;* the other an elastic firm jelly, of a crimson-red colour and thick consistence, resembling a deposit, which is called the *clot*. If this clot be repeatedly washed with cold water, it parts with its red colour to the water, becomes white, and a fibrous matter remains, which, when subjected to analysis, proves to be *fibrin*. Serum coagulates when heated to about 160°, nearly in the same manner as the white of an egg, but the colour is not pure white. If the serum thus coagulated be cut in slices, a fluid will exude which is called the *serosity* of blood; it consists chiefly of water, holding a little altered albumen and a little common salt in solution. Serum is composed of water, albumen, soda, and some salts of soda. Clot is composed of fibrin, albumen, red colouring matter, a little iron, and carbonic acid. During the conversion of arterial into venous blood (as explained under ANIMAL PHYSIOLOGY), nitrogen, hydrogen, and other elements are spent in the formation of new products, while the proximate principles of the blood remain, with an increased proportion of carbon. In this state it is exposed to the atmospheric air in the lungs, the oxygen of which abstracts its excess of carbon, and forms the carbonic acid expired; and this process constitutes the conversion of venous into arterial blood.

CHEMISTRY APPLIED TO THE ARTS.

CHEMISTRY, or that department of physical science which recognises the nature and composition of bodies, and the new forms and properties they may be made to assume, is now indispensable to the proper conducting of almost every useful art. Agriculture, which may be considered the most important of all the arts, is radically dependent on chemistry; for without a knowledge of that science, the husbandman remains ignorant of the constitution of his soils and crops, the action of the atmosphere and sun's light, and the properties of those materials which are required to enrich his exhausted fields. Baking, brewing, distilling, and indeed all the operations by which food is prepared from the condition in which it is furnished by nature, are in general a series of chemical processes. So, likewise, is the manufacture of pottery-ware, porcelain, glass, paper; the operations of bleaching, dyeing, and calico-printing; the preparation of soap, gunpowder, ink, salt, drugs, paints, perfumery, and various other articles in daily demand. The applications of chemistry to the arts extend to the whole circle of manufacturing industry. In the present sheet, a short account will be given of the manner in which chemistry is practically applied in the more important of those industrial operations to which we have not elsewhere alluded. The design in view is not to teach any one art, but to incite to a *general study of chemistry* among those classes who are engaged in such branches of manufacture as involve an elementary change in substances. Manufactures of this kind may be termed *chemical*, in contradistinction to those whose elaboration mainly depends upon principles that are *mechanical*. Thus, the conversion of sand, potash, and lime, into glass; of common salt into soda; iron ore into metallic iron; hides into leather; and charcoal, sulphur, and saltpetre, into gunpowder, are chiefly chemical processes: while the conversion of flax into cloth, and clay into pottery, are principally mechanical, though in both there is a necessary blending of chemical with mechanical appliances. 'Technology' being a systematic exposition of the principles upon which all processes employed in the arts are based, CHEMICAL TECHNOLOGY may be regarded as the scientific title of the present subject.

ACETIC ACID.

Acetic acid, or the sour principle in vinegar, is obtained either by the slow combustion of a liquid containing alcohol, or by the destructive distillation of wood. The former method yields the best flavoured vinegar, and is generally preferred where the acetic acid is to be used as a condiment. The alcoholic liquids employed in its manufacture are wine, beer, &c., which, when exposed to the action of the air, become sour, by the slow passage of the spirituous ingredient present in them into acetic acid. *Wine-vinegar*, as its name implies, is derived from wine, and is the most pleasant of all, as it contains, besides the real acid, some acetic ether, which imparts a pleasant *bouquet* to it; *alcohol vinegar* is manufactured from spirits; *cider vinegar* owes its origin to the juice of apples; *beer* or *malt vinegar* is prepared from the extract of grain, and is the most common variety. Pure alcohol might be kept for months and years, even exposed to atmospheric influence, and, provided evaporation were guarded against, the liquid would not change in bulk or character; but if any putrefying matter or *ferment*, and, best of all, *yeast*, be added, the alcohol passes into acetic acid. It must be noticed that this action is not fermentation, in the strict sense of the term, but is rather an instance of slow combustion. The several atoms of carbon, hydrogen, and oxygen, comprising the alcohol atom, are not simply rearranged, but a supply of oxygen is absorbed, two of the atoms of hydrogen are burned away, and two atoms of oxygen take their place.

There are two methods followed in the preparation of vinegar from alcoholic liquids: the *old* or *slow* process, which occupies some months, and the *new* or *quick* method, which requires only a few days. The former is that which is generally followed in the United Kingdom, and consists in placing stale beer, ale, or porter, or where these cannot be had, a decoction of malt, called wort (see Beer), in casks lying on their side with their bung-holes left open. The liquid fills the hogshead about two-thirds, and the remaining space is occupied by atmospheric air. After the true alcoholic fermentation has ceased (see Alcohol), the oxygen of the air is absorbed, and the combustion of the alcohol into acetic acid takes place. After some months, the change is complete; the liquid is pumped into a large store vat, where it settles; and thereafter it is clarified, by being passed through a filter composed of the stalks and skins of raisins obtained as the refuse of the British wine-manufactories.

The *quick* process depends for its rapidity on the more ready access of air to the liquid undergoing acetification. This is accomplished in a hogshead placed on its end in the ordinary way (fig. 1), and fitted up in the interior

Fig. 1.

with a grating or false bottom, about one foot higher than the real bottom. Above this false bottom are piled curled beech-shavings, soaked in vinegar, which reach near the top; whilst round the sides of the cask a number of holes are bored, so as to admit of the access of air. When the process is in operation, the liquid to be acetified is allowed to trickle slowly through openings in the top of the cask, and then falling on the shavings, is spread over a large surface, and the thinnest films of liquid thus brought into contact with the air in the interior of the cask. The result is, that the combustion of the spirituous matter into vinegar is almost, if not entirely, complete, by the time the liquid finds its way through the pile of shavings to the lower part of the barrel. The heat evolved during the chemical change assists greatly in causing a draught of air through the whole arrangement. In this manner, a volume of liquid containing one of alcohol to five of water, mixed with $\frac{1}{1000}$ of a ferment, can be readily transformed into vinegar.

A third method of procuring acetic acid is by the destructive distillation of wood. Pieces of timber are placed in an iron cylinder or retort, and heat applied. Gases and vapours are evolved, which are conducted by a pipe to a cool receiver, whilst at the same time much charcoal is left in the retort. The vapours which condense to liquids in the receiver are composed principally of pyroxylic spirit (wood-spirit) and pyroligneous acid (vinegar) accompanied by a little tar, creasote, &c. This mixture of liquids is redistilled, which vaporises the wood-spirit, and leaves the other matters in great part behind. The latter are neutralised by slaked lime, which combines with the vinegar to form acetate of lime, a salt soluble in water. On the addition of sulphate of soda to this solution, an interchange of acids takes place, and the acetic acid combining with the soda, becomes acetate of soda. The solution of the latter is evaporated to concentration, and allowed to crystallise; the crystals are separated from the impure mother-liquid, and after being dried, are calcined, to destroy any tarry matters which may still be present. The calcined mass is digested in water, which dissolves out the acetate of soda; and this solution, treated with sulphuric acid, placed in a retort, and subjected to heat, yields acetic acid or vinegar, which distils over.

The impurities liable to be present in vinegar are, sulphuric acid, lead, and copper. Sulphuric acid is allowed by law to the extent of $\frac{1}{1000}$ of the volume of the vinegar, in order to put a stop to *mothering*, or the appearance of fungus-growth in it; but in many cases it is fraudulently added, for the purpose of imparting a smarting taste to very dilute or watered vinegar. The lead and copper sometimes to be found, are doubtless derived from the pans, retorts, or reservoirs in which the vinegar is manufactured or stored; but care should be taken to exclude such metals, as they become dangerous poisons when partaken of in quantity.

ALCOHOL.

The spirituous or intoxicating principle in fermented liquors, is called by the chemist *alcohol*. The variety best known in this country is that derived from grain, in the preparation of which four distinct processes are successively followed—namely, *mashing*, *cooling*, *fermenting*, and *distilling*.

The *mashing* consists in taking a certain amount of barley, ground to a fine meal, and crushed malt (see Beer), placing them in a large tun, and covering them with water at a temperature of 150° Fahrenheit. The whole is kept agitated for some hours, during which time fresh quantities of warm water are added, and then the whole is left at rest for two or three hours for *infusion*. During these processes, the starch in the grain is in great part converted into sugar, and this dissolving in the water, forms a sweet liquid called the *wort*. The latter is drawn off from the grain, and more water added to the solid residue, which yields a larger supply of sweet wort. After several washings, the greater part of the sugar has been extracted in the wort.

The *cooling* of the wort must be quickly accomplished; and in order to effect this, the warm liquid is run into shallow wooden pans or troughs, to the depth of an inch or two, and as cool a breeze as possible, aided by cold-water pipes or fanners, soon reduces the temperature.

The *fermentation* process is that which must be most carefully watched, as a slight cause may risk the loss of the entire liquor. The process consists in the addition to the saccharine solution or wort of a minute amount of a ferment such as yeast. The latter contains a multitude of little globular bodies belonging to the vegetable kingdom (fig. 2), which always make their appearance during the putrefying of nitrogenised matter. A solution containing sugar and albumen, and to which no yeast has been added, will develop, at a temperature ranging between 64° and 77°, myriads of specimens of this yeast-plant. The distiller generally procures his yeast from the porter or ale brewer, and adds it to the wort in a large fermenting tun. No sooner do the yeast-granules meet the sugar-atoms, than a chemical decomposition commences. The sugar particles are split up partly into carbonic acid gas, which, in its escape from the tun, causes much frothing of the liquid, and in other part into alcohol, which remains behind in the liquid. (See Beer.) Notwithstanding the great commercial results attendant on this process of fermentation, yet the manner in which the yeast-plants affect the passage of the sugar into alcohol and carbonic acid, still remains a mystery. Some chemists speculate so far as to think it possible that the particles of the yeast, being themselves in a state of motion, may cause, by mere contact, motion to be communicated to the particles of sugar; whilst others consider it possible that the yeast-plant lives upon the sugar, and evolves, as the effete matters of its growth and life, carbonic acid and alcohol. Neither view accounts for the phenomenon. Notwithstanding our incapability to explain the cause, it is a fact that the sweet wort obtained in the *malting* and *cooling* processes, does undergo a change when yeast is added to it; and after some days, the greater portion of the sugar has been transformed into carbonic acid and alcohol. When such takes place, the liquor or *wash*, as it is now called, is ready for the next operation.

Fig. 2.

The *distillation* process consists in separating the alcohol from much of the water, as likewise the other substances with which it is contaminated in the *wash*. For this purpose, on the small scale, in laboratory experiments, the liquid is placed in a glass retort attached to a cooled receiver, and heat being applied, the alcohol, accompanied by a little water, passes over into the cool end of the arrangement. On the large scale, the distillation is conducted in a metal boiler with a large head terminating in a tubular beak (fig. 3). The latter is attached

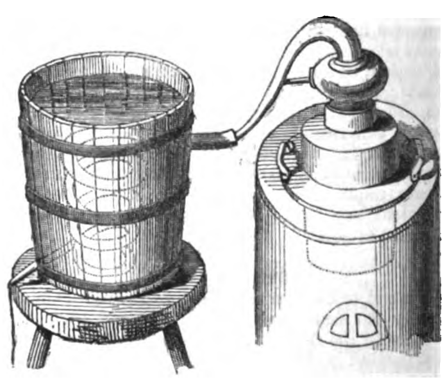


Fig. 3.

to, and communicates with, a long metal tube coiled round the interior of a barrel filled with cold water. The liquid to be distilled is placed in the boiler, a fire lit below, and the alcoholic steam rising to the head, passes into and through the coiled tube or *worm*, is there condensed, and runs from it as a cold liquid. This is the form of still used some years ago in all distilleries, as likewise in illicit distillation, but now a days very complicated and expensive apparatus is employed instead. The later improvements have been made with the view of hastening the operation; and so much is this the case, that a quantity of *wash* which, by the older stills, would have required a week for its distillation, is now worked off in a few minutes. A weak spirit—containing much water—is often obtained by the first distillation, and this is called *low wines*.

By a second distillation, the first portions which pass over are procured of a much greater strength, technically termed *doublings*.

The alcohol of commerce is always a mixture of chemically pure alcohol and water. The recognised standard is *proof*-spirit, which contains 49·50 per cent., by weight, of absolute or pure alcohol, and 57·27 per cent., by volume, with a specific gravity of 918·6. What is called *spirit of wine* or *rectified spirit* is much stronger, and has a specific gravity of 838 at 60° F. *Ardent spirits*, such as whisky, gin, rum, and brandy, are made up of alcohol, water, volatile oils, and colouring-matter, and generally contain between 40 and 50 per cent. of alcohol. Wines, such as sherry, port, claret, &c., are less strong, having only 15 to 25 per cent. of alcohol present; whilst ale, porter, and beer contain from 1 to 8 per cent.

Alcohol is used in the arts and manufactures, for the solution of resins, in the preparation of the better kind of varnishes, and as a solvent of the essential oils, &c., when it forms a numerous class of *tinctures*. Eau de Cologne is simply a tincture or solution of certain volatile oils in alcohol. As a source of heat, alcohol has long been used by the chemist in his spirit-lamps, and likewise as a solvent for many saline substances, it has proved itself useful in many ways.

The high price of alcohol in this country, and the many uses to which it might be put with great commercial advantage and profit, led the British government to introduce into our manufactures, on the 1st October 1855, a new variety of alcohol, under the name of *Methylated spirit*. This liquid is ordinary spirit of wine, to which there has been added one-ninth of its volume of wood-spirit (methylated alcohol). Such a spirit is allowed to pass into commerce duty free, and has proved itself as useful as the pure alcohol in all those arts and manufactures where such was required. The only restrictions as to its obtainment and use are such as are deemed necessary for the purpose of avoiding the methylated spirit being used as an intoxicating agent. It is not likely, however, that with the most unrestricted sale, it would ever take the place of whisky or other liqueur, as the disagreeable odour and taste of methylated alcohol renders any mixture which it may form part of, at once unpalatable. The new spirit is, however, largely employed as a solvent of varnishes and polishes, and is also employed in the manufacture of fulminating mercury, ether, and chloroform. From its antiseptic powers, the anatomist finds it of much use, as a means of preserving delicate animal membranes and other anatomical specimens.

BEER.

The raw material from which the fermented liquors in this country are prepared is barley. Pease, beans, wheat, &c., might do, but are not so readily or economically advantageous. The production of beer occupies two distinct processes—namely, *malting* and *brewing*. The latter was referred to at some length under Alcohol, but will require some further remarks here.

The passage of barley into malt is accomplished by successive steps. The *steeping* process consists in placing the barley in a large square stone box, where it is covered with water, and allowed to remain at least forty hours. Here the grain absorbs one-half its weight of water, and swells up. The superfluous water is then drained off, and the wet barley is thrown out in a heap on the floor. There it undergoes the process of *couching*, which takes place by allowing the grain to lie in the heap till it becomes warm and sweats, and ultimately the roots begin to appear. When the sprouting has proceeded some length, the plan of *flooring* is resorted to, to stop the germination. This is accomplished by spreading out the heap of grain to the depth of about six inches, and repeatedly turning it over during twelve days. The last stage of the operation is *kiln-drying*. The grain is placed on a perforated iron floor, and hot air being passed up through the openings, the barley is dried. During malting, 100 pounds of barley become eighty pounds of malt, but the deficiency is not all loss. Originally, twelve pounds of moisture are present in the grain, and this quantity deducted from the apparent loss, leaves only eight pounds of real loss during the operation. Bulk for bulk, however, the malt slightly exceeds that of the barley started with.

The chemical changes which take place during the conversion of barley into malt are considerable. Much of a woody substance called hordein is changed into starch and gum, and some starch and gum become sugar. The following table represents these changes in figures:—

	Barley.	Malt.
Hordein,	55	12
Starch,	32	56
Sugar,	5	15
Gluten,	3	1
Gum,	4	15
Resin,	1	1
	100	100

These changes proceed whilst the plumule or primary stem is advancing in growth. When the grain is kiln-dried, the roots, &c.—technically called *cummings* or *cornings*—are separated from the true body of the seed by a revolving machine. The particular kind of malt is named according to the depth of colour which it presents after heating. There are four kinds well known —*pale malt*, *amber malt*, *brown malt*, and *black malt*. The two last are somewhat charred, and are employed in the preparation of porter.

The first stage in *brewing* is the *grinding of the malt*. When reduced to coarse particles, the bruised malt is thrown into a large mash-tun, and there the process of *mashing the malt* is gone through. Water at a temperature of 160° F. is poured over the malt, and repeatedly agitated. During this stage, a substance called diastase is developed in it, which converts the remaining starch into sugar. The resulting *sweet wort* is run into the *underback*, a large reservoir, where it is graduated to the proper strength. At the same time, the insoluble matter of the malt, called draff, is carried off to feed cattle. The *boiling of the worts* takes place in a large copper, when the *hops* are added. The heating of the liquid coagulates the albuminous (white of egg) matters present—technically called *cutting the worts*—and likewise serves to extract the volatile oil, bitter resin, and tannin from the hops. The liquid is then strained, and rapidly cooled in large shallow troughs, assisted by fanners or refrigerators. After cooling, the sweet liquid is placed in the *fermenting-tuns*, the yeast added, and the fermentation process allowed to take place. (See Alcohol.) When successful, a fine light-coloured froth or head should appear, somewhat resembling *rocks*. A dark-coloured head betokens bad fermentation, and results in bad beer. The liquid, attenuated to the strength required, stands for some days to clear, and lastly is stored in barrels, where more hops are often added.

Ale for the home-market contains 5 to 7 per cent. of alcohol, and retains much sugar. That for the foreign market—such as East India pale ale—is more *attenuated* (*i. e.*, more of the sugar is converted into alcohol), and contains 10 per cent. of alcohol; whilst that forwarded to California is still stronger in alcohol, or is more *dry*. Small-beer can only boast of 1 per cent. of the intoxicating principle.

The preparation of *wine* depends on the same principles as those which regulate the production of beer. There are fewer stages, however, in the process, depending on the fact, that the material in the grape to be converted into alcohol is already sugar; whilst in the case of barley, it is mostly hordein, which must become starch, then gum, then sugar, before it is ready to undergo fermentation. In the manufacture of wine, the bruised grapes are put into a vessel, and allowed to

stand for some time, exposed to the ordinary temperature of summer. At the end of a certain period, the liquor becomes muddy; an internal motion takes place, and sometimes the temperature is found to be elevated; air-bubbles rise to the surface, occasioning a bubbling noise when they break; and the bulk of the liquid being increased, it has a tendency to boil over. From this circumstance, the process is called fermentation, from the Latin word *fervere*, to boil. The bubbles created rise to the surface, involved in a viscid matter, the whole resembling froth, which, parting with the air, subsides to the bottom, and the liquor becomes tranquil and transparent. This viscid matter is the *yeast* or *barm*. The sugar in the grape-juice has now been entirely changed into carbonic acid and alcohol, and the process is termed *vinous fermentation*.

Cider is the expressed and fermented juice of apples, and *Perry* is that of pears. Their mode of production is similar to that of wine.

BLEACHING.

Bleaching is the art by which various articles may be deprived of the colours which they naturally possess, and so rendered white. Formerly, it was the custom to submit textile fabrics in a moist condition to the free action of the atmosphere and sun's light; but this process of bleaching was tedious; and the substitution of a chemical effect, as suggested by the celebrated chemist Berthollet (1787), was a great improvement, such as the state of manufacturing industry required. Berthollet's plan consisted in employing chlorine, which possesses a wonderful power of removing vegetable colouring-matters from cotton and linen goods without injuring the fibre. The bleaching-powder, or chloride of lime, as it is usually called, is manufactured by exposing slaked lime (hydrate of lime) to the action of chlorine gas, till as much of the latter is absorbed as the lime is capable of combining with under these circumstances. The chlorine in the bleaching-powder acts upon vegetable substances by abstracting the hydrogen of the colouring-matter, and thereby compelling it to lose its hold of the cloth to which it adheres; the air would have the same effect, but would require a much longer time than can be, commercially speaking, allowed. The cloth is first singed by being quickly passed over red-hot iron cylinders, or a series of gas jets; washed repeatedly in water, alkaline lyes and soap; placed in a cold solution of the bleaching-powder for about six hours (*chemicking*), and is then taken out and washed with water. The next part of the process is called *souring*, which consists in immersing the cloth in a solution of sulphuric acid, so diluted that it does not injure the texture of the goods, whilst it improves their colour. The sulphuric acid acts on the bleaching-liquor absorbed into the fibre of the cloth, combines with the lime, and sets free the chlorine, which bleaches the cloth. The acid likewise dissolves and removes any oxide of iron with which the fabric may be contaminated, as also the lime which may have attached itself to the woven material during its treatment with the bleaching-liquor. The cloth is again washed with water, boiled in an alkaline lye, and once more carefully washed in cold water. Another solution of bleaching-powder, two-thirds the strength of the former, is then prepared, in which the cloth is immersed, and left for five or six hours, when it finally undergoes the process of souring, by which it is rendered perfectly white. The acid is carefully removed by washing. The cloth is then dried, and after each piece is stretched to its full length, it undergoes a process of mangling, by being passed successively between cylinders forced towards each other by levers, to which a considerable weight is attached. The cloth being thus stretched, smoothed, and wound upon a roller, is rendered fit for *starching*. The starch is that of wheat-flour, deprived of its gluten by remaining for twenty-four hours in water, and then passed through a sieve, which retains the bran, and allows the starch to pass. A little indigo is mixed with it, and sometimes porcelain clay. The starch is applied in the state of a pretty thick paste whilst the cloth is passing between a pair of rollers. The goods are then dried, and passed through a calender, for the purpose of giving them a gloss and texture.

Woollen and silk goods cannot be bleached by chlorine. To whiten woollen yarns and cloth, burning *sulphur* is employed. The operation is conducted in a small wooden house, in which the goods are suspended, along with a pan containing pieces of sulphur, which is set fire to by a red-hot iron being plunged into it. The doors, &c., being tightly closed, the fumes of sulphurous acid rise and fill the chamber, at the same time attacking and bleaching the wool. This operation is preceded and succeeded by numerous washings of the goods with water, alkaline lyes, and soap.

Of late years, the discoveries in scientific chemistry would lead us to anticipate that, at no distant date, the bleacher will return to a modification of the process, now antiquated, of exposing the cloth to be bleached to the action of atmospheric agents. The substance ozone (see CHEMISTRY), lately observed to be an ordinary constituent of the atmosphere, is now supposed to have been the agent which in olden times used to bleach our cloths as they lay exposed for months to wind and weather; and as ozone, when obtained in strength, has been found a most powerful bleacher, it is not too much to assert that, if it could be economically prepared, ozone would soon outrival chlorine as a bleaching agent.

CALICO-PRINTING.

The art of calico-printing consists in impressing the representation of certain figures or designs upon cloth. The mechanical part of the process consists in placing the colour on figures raised in metal or wood, and then stamping these on the cloth; or by engraving characters on a copper roller attached to a printing-machine, which fills the indentations with colour, and as the cloth passes through, allows that colour to adhere thereto. So perfect has the printing-machine now become, that a series of five or six colours can readily be fastened by the cloth passing only once through.

A piece of cloth intended for printing is first singed, bleached, and calendered. Before the application of the colour, it is often necessary to print on a *mordant*, which is generally a salt of a metal, which sinks into the cloth, and adheres firmly to the tissue. The most common mordants are salts of alumina, iron, and tin. The great use of the mordant is to absorb and retain the colour when it is printed on. Were no mordant employed, the colouring-matter would remain soluble, and the first washing the cloth received would carry much of it away; but the mordant has a great affinity for the colour, and combines with it to form an insoluble compound. Both the mordant and the colour require to be thickened, so as to give them consistence, and for that purpose gum-arabic, British gum (torrefied or heated starch), &c., are added. The proper thickening of the mordants and colours is of great importance, as it assists in stopping the running of the liquid over the cloth, and thereby gives fixity to the pattern. In impressing the representation of figures on calico goods, the object often held in view is the fixing of mordants on the cloth, which is afterwards dyed in the usual way, those parts alone which have received the mordant retaining the colour, the rest remaining white. The application, or the bringing out of the colours, is an ingenious chemical process. Madder is the substance commonly used for red by the calico-printers, and the addition of sumach, fustic, or quercitron bark, will produce a variety of tints with the various mordants at one operation. 'Suppose,' says Dr Ure, 'we wish to produce flowers or figures of any kind, containing red, purple, and black colours, we may apply the three mordants at once by the three-colour cylinder machine, putting into the first trough acetate of alumina

thickened; into the second, acetate of iron; and into the third, a mixture of the two; then drying in the air for a few days, to fix the iron, dunging, and dyeing up in a bath of madder and sumach. If we wish to procure the finest madder reds and pinks, besides the purple and black, we must apply at first only the acetate of alumina of two densities, by two cylinders; dry, dung, and dye up in a madder-bath. The mordants of iron liquor for the black, and of iron liquor, mixed with aluminous, for the purple, must be now grounded in by blocks, taking care to insert these mordants into their precise spots; the goods being then dried with airing for several days, and next dunged, are dyed up in a bath of madder and sumach. They must be afterwards cleared by branning.'

In some cases, the colour is removed from certain portions of cloth already dyed, so that they may either remain white, or receive some new colour afterwards. Sometimes a preparation is applied to cloth before it is dyed blue, in order to prevent the indigo from being fixed on those parts to which it is applied, so that they may remain white, or receive other colours. Substances possessed of this property are called resist-pastes.

After the cloth is dyed, it is washed either with soda, potash, soap, or fresh water, according to the nature of the ingredients used in the dyeing process. Great care is necessary in this department; for if the washing-liquor be too strong, the mordant may be injured. Cow-dung, diffused through hot water, is applied to calico goods at a particular stage of the manufacture. This is done in order to dissolve and carry off from the cloth a portion of the thickening matter, and also to prevent any undissolved mordant or acetic acid from injuring the blank parts of the piece. The dunging, as it is called, is performed several times, generally between the washings. The piece should be immersed, if possible, without folds; and to secure this, it is made to pass through rollers. As soon as it comes out of the dung-bath, it is washed in the dash-wheel, as in bleaching. The cloth is then finished by being passed through a calender, which greatly improves its appearance.

CANDLES.

Common tallow forms the material from which the cheaper candles are prepared. Ox-fat is first melted, which enables the fibrous and membranous parts to separate, rise to the surface, and be skimmed off, whilst the truly oleaginous matter remains liquid underneath. The skimmings are squeezed in a press, to extract any adhering fat, and the residue is sold as *greaves* or *cracklings*, to feed dogs, &c. The melted fat is poured into moulds, and stored till required by the candlemaker. Tallow-candles are known as *dips* or *moulds*, according to the particular process they pass through. The apparatus required in the preparation of dips is an upright post supporting a wheel with eight to twelve horizontal arms like spokes, at the further end of each of which dangles a light framework, with 100 to 150 cotton-wicks suspended thereto. The operation commences by bringing one of the spokes, with its host of wicks, right over a trough containing melted tallow, and ducking the wicks therein for a minute or so, when they are withdrawn, and resume their station mid air. The wheel is then moved round a peg, and a second spoke with wicks attached is brought above the trough with melted tallow, and the ducking, &c., takes place again. Then the third and fourth spokes have their turn in the tallow-bath; and this process goes on round and round the wheel till all the wicks attached to the spokes present the required thickness of combustible matter. By such an arrangement as has been described, one man will suspend, dip, and prepare 1500 candles an hour, which gives the work of one day as no less than 15,000 dips. *Moulds* are of a firmer texture than the *dip*-candle, and are prepared from a mixture of ox-tallow and mutton suet. In their manufacture, a pewter mould, the same shape as the candle, is employed, which has a wick suspended in the centre, and into which the melted mixture of tallow and suet is poured. These common varieties of tallow-candle—namely, the dip and the mould—have now been, to a very great extent, superseded by those prepared by a more modern process, which yields candles of such excellence that they rival the best wax. This process is one which involves a certain amount of knowledge regarding the chemistry of the more common fatty substances, which we now proceed to give.

Some years ago, M. Chevreul, a French chemist, undertook an investigation into the nature of fatty substances, which he found to be composed of what we now know them to be—two materials, *stearine* and *oleine*. He ascertained that the oil does not combine directly with an alkali, but that its two components are decomposed by it into two corresponding acids, the stearic and oleic, and a basic body called *glycerine*, with which both are naturally in combination.

M. Chevreul separated these acids from their compounds, and found them possessed of the following properties:—Oleic acid is a liquid, clear when pure, and closely resembling oil; stearic acid is solid, and resembles wax in so striking a manner as to be with difficulty distinguished from it. If the reader wishes to prepare and examine the artificial wax himself, it may be easily accomplished. Let him dissolve a little hard white soap in hot rain or distilled water, and to the clear solution, while hot, add some vinegar or other acid. The stearic, being a weak acid, is easily separated from its combination with soda, as it exists in soap. Acetate of soda is formed, which remains in solution, and the stearic acid rises to the top of the liquid as an oily substance, which, on cooling, solidifies into a cake of artificial wax, mixed with a certain portion of oleic acid and impurities, which render it softer than if this fluid had been expelled by pressure. A similar process is pursued on a large scale, but regard must be had to economy. The tallow is saponified, not by soda or potash, as in the preparation of soap, but by quicklime. It is only necessary to boil the lime, tallow, and water in a large vessel for some hours, when these ingredients are converted into a kind of hard soap. From this substance—namely, the stearate and oleate of lime—the stearic and oleic acids are separated by the addition of oil of vitriol. The acids are afterwards melted like tallow, run into cakes, and subjected to the powerful action of a hydraulic-press; this separates all impurities, and leaves the stearic acid as pure and white as the finest bleached wax, which may be used immediately for the formation of candles. In France, the wicks, besides being plaited, are dipped in a solution of borax, and then dried. The borax fuses during the combustion, and forming a globule on the summit of the wick, assists by its weight to bring it out of the flame in contact with the atmosphere, and thus insures perfect combustion, and obviates the necessity of snuffing. Palmer, an English patentee, accomplishes the same end by making the wick consist of two halves, which are twisted in opposite directions, and at the same time wrapped round a rod or wire, which is withdrawn when the candle is made. The result is, that the halves separate on combustion, and fork outwards to the exterior portion of the flame, where they are completely consumed.

It was found that the artificial wax generally crystallised in the moulds—a circumstance which prevented the formation of a solid candle. In England, this difficulty was overcome in some cases by the addition of arsenic; but the use of this substance either for this purpose, or for causing the wicks to be more readily reduced to ash, ought never to be permitted, as it is highly prejudicial to health. The French, more scientific than we, had recourse to their knowledge of the laws of crystallisation for the remedy. It is known that regular crystallisation only takes place when the transition

of the mass from a fluid to a solid state is so gradual, as to allow time for its molecules to arrange themselves in those determinate forms called crystals: this condition was fulfilled in the cooling of the moulds and their contents; but by plunging them in cold water as soon as the melted stearic acid had been poured in, crystallisation was prevented, and a perfectly solid candle procured. Stearic candles, which can with difficulty be distinguished from wax-candles, are now manufactured on a large scale in England, and, from their comparative cheapness, are coming universally into use in the houses of the middle and higher classes of society.

More recently, palm-oil has been introduced and used with great success as a source of material for candles. This oil consists of palmitine (composed of palmitic acid and glycerine, and resembling stearine) and oleine. As brought to this country, it is a soft solid of the consistence of butter, and of an orange-yellow colour. In order to bleach the oil, it is thrown on hot water, when it readily fuses; it is then either simply exposed to the sun's light and the presence of air, when it becomes white in about fifteen hours; or, whilst in a state of fusion, it is acted upon by bichromate of potash and sulphuric acid (or hydrochloric acid), which evolve nascent oxygen, and the oil is bleached in five minutes or so. After being washed, the purified oil is saponified by lime, as before detailed, and sulphuric acid is thereafter added, to separate the oleic and palmitic acids. The latter is a fine white solid, and is now most extensively employed in the manufacture of imitation wax-candles. Coco-nut oil, bees-wax, and an African vegetable wax, are also employed. Mixtures of the several oils and waxes are often desirable. Equal parts of stearine and coco-nut oil, with a little bee and African wax, make *composite candles;* whilst a mixture of spermaceti and stearine gives the *opaline sperm-candles*, much liked, and generally used on board sea-going steamers.

Glycerine.—In connection with the manufacture of candles, we have to allude to the substance which is separated from the oils in the preparation of the stearic and palmitic acid. By the ordinary process of saponifying the oil with lime along with water, the glycerine was separated in the water in an impure state, and it was only by a tedious operation that the pure material was arrived at. In 1855, however, a new process was suggested, and has been carried out on the large scale, in which lime is dispensed with, and the oil is decomposed, and its glycerine separated by means of heat and steam alone. The palm-oil is introduced into a capacious distilling apparatus, and steam at a temperature of 550° to 600° Fahrenheit forced through the oil. The components of the oil, principally palmitic acid and glycerine, are separated from each other, severally combine with water, and then distil over, mechanically mixed, as the palmitate of water and the hydrate of glycerine. The former, being the lighter of the two, swims on the surface of the mixed fluids, whilst the glycerine remains dissolved in the great bulk of water (condensed steam) underneath. When first distilled, the solution is weak, and requires to be concentrated; and if at all discoloured, can be purified by redistillation. It is then obtained of the specific gravity of 1240, and contains 94 per cent. of anhydrous glycerine. The purposes to which glycerine may be applied are numerous. It possesses a great power of preserving animal matter from decay. Fish, when newly caught and immersed in glycerine, not only remain fresh to taste and smell, but likewise retain the colour of their scales as perfect as when they were sporting in their native element. Anatomical specimens can likewise be preserved in all their integrity. It is useful in skin diseases, as also in chapped hands and sunburnt faces. In some instances it can be advantageously substituted for sugar or sirup in the maintaining of medicines in their active state, and in the preservation of fruits, of which it is supposed by many to improve the taste. As an agent in photography, glycerine seems likely to occupy a high place; and as a material to inject into the bladder for the purpose of dissolving calculous deposits, it has been deemed worthy of trial.

CHLOROFORM.

This important substance is prepared from four parts of bleaching-powder, one part alcohol, and twelve parts of water. The bleaching-powder and water are first intimately mixed together, introduced into a capacious distilling apparatus, thereafter the alcohol added, and heat applied. A liquid distils over, which is in greater part water, accompanied by a little alcohol; but underneath the stratum of water will be observed globules of an oily-looking substance. This is the chloroform, which is purified by washing with water, and redistillation from a retort containing chloride of calcium. The cheap methylated spirit may be employed in this process; and the large quantities of chloroform now prepared from the cheaper spirit, cannot be distinguished from that manufactured from pure grain alcohol. Chloroform is a very volatile liquid, with a density a little less than 1500, and is slightly combustible, burning with a greenish flame. It is sparingly soluble in water, and should not be coloured by cold sulphuric acid. When sparingly given to an animal, it brings on a period of excitement; but when administered in comparatively large doses, it produces insensibility to pain, so that the most severe surgical operations can be performed whilst the patient is enjoying unbroken slumber. (See MEDICINE AND SURGERY.)

COLOURS—PIGMENTS.

There are, as is well known, two modes of imparting colours—dyeing and painting; the former term being applied to articles coloured by a liquid infusion, and the latter to the laying of a colouring substance on the surface. We *dye* cloth, and *paint* a house. The materials employed in dyeing are usually drugs, salts of some kind, or vegetable fluids; but in painting, the prepared colours are chiefly pigments. The preparation of dye-stuffs and pigments is one of the chief departments of practical chemistry.

The substances used as *paints* are partly artificial, and partly natural productions. They are derived chiefly from minerals by certain chemical processes; and even when animal or vegetable substances are used for colouring, they are always united with a mineral substance (an earth or an oxide), because by themselves they have no body, which they acquire only by a mixture with a mineral. In painting, the colours are ground to a great degree of fineness, and applied, by means of some liquid, with a brush or camel-hair pencil. Different fluids are employed for this purpose; and the difference of the material used, with the method of employing it, has given rise to the modes of painting in water-colours, oil-colours, in distemper, and in fresco (painting on damp plaster as an absorbent). Oil-paints are usually prepared with boiled linseed-oil, which is drying in its nature; the colours employed all consist of metallic oxides, or salts, or of combinations of sulphur. Among the metallic oxides used as pigments are minium and massicot, from lead; the ochres, burnt sienna, umber, from iron; smalt, from cobalt. Among the salts, or saline metallic combinations, are white-lead, kremnitz white, from lead; Prussian blue, from iron; verdigris, mineral green, Brunswick green, from copper. Metallic combinations containing sulphur are cinnabar, from quicksilver, and orpiment, from arsenic. The lake colours have tin or alum for their bases, and owe their tint to animal or vegetable colouring substances. Among these are the red or pinkish lakes prepared from cochineal, madder, and Brazil-wood; the yellow, from fustic, &c.; the brown, from several other colouring barks; finally, indigo, which, however, is entirely vegetable. In

staining porcelain and glass, the metallic colours which are not driven off by heat, and are not easily changeable, are used. Gold containing tin gives a purple; nickel, green; cobalt, blue; iron and manganese, black; uranium, yellow; chrome, green. From the chromate of iron, or rather ferruginous oxide of chrome, one of the most beautiful yellow pigments is now prepared for the use of painters. Ultramarine, another of our most beautiful, and, till lately, one of the most expensive of our pigments, was originally obtained from the lapis-lazuli, a mineral of unrivalled azure blue, and composed of silica, alumina, and soda, three colourless bodies, with sulphur, and a trace of iron. It is now prepared artificially by combining those substances in their proper proportions.

The material principally employed by respectable house-painters to give consistency to their paints, is white-lead or ceruse. This substance is an oxide of lead saturated with carbonic acid. It is prepared by exposing thin plates of lead in a closed vessel to the vapours arising from hot vinegar. The vapours of the acetic acid become saturated with the metal, and change the latter into a whitish substance, which is scraped from time to time off the plates. The whitish substance is afterwards pulverised, and mixed with properly prepared oil. Much of the white-lead in common use is adulterated with whiting—that is, purified and ground chalk—which is much less durable, and may be easily washed off by an alkaline solution.

More recently white-lead has been extensively adulterated with ground heavy spar, or sulphate of baryta. This substance occurs largely in cracks or fissures in rocks, especially in the island of Arran, and is readily purified from the oxide of iron with which it is coloured, by being ground to powder, and digested in dilute sulphuric acid. When purified, it yields a fine white powder, which, so far as regards weight, rivals ordinary white-lead; but as it does not form a body with linseed-oil, its presence in the white-lead of commerce is always injurious. This form of adulteration is carried on to a very large extent, and even the coloured paints suffer, as the ground heavy-spar is likewise manufactured as a yellow powder, by the addition of a little chromate of lead, as a blue compound from admixture with Prussian blue, and as a green pigment by the addition of both chromate of lead and Prussian blue. So much is this adulteration carried on at the present day, that no less than three mixtures of white-lead with sulphate of baryta are regularly prepared for, and sold in the market. *Venice white* contains equal parts of white-lead and sulphate of baryta; *Hamburg white* is a mixture of one part white-lead and two parts of the baryta compound; and *Dutch white* is composed of one part white-lead, and no less than three of the comparatively useless sulphate of baryta. Pure white-lead is known in commerce as *krems* or *kremnitz white*, *silver white*, and the *clichy white*. A little indigo or lampblack is often added, to impart a blue tint to the white-lead.

Oil or spirit of turpentine is also largely used by house-painters, who style it *turps*, chiefly for the purpose of imparting a drying quality, or of deadening the glitter of the paint. Turpentine is a fluid extract from certain kinds of fir-trees, from which it exudes, and being distilled, the oil or spirit of turpentine is obtained; the residuum is resin. Turpentine is of a powerful acrid quality, and is now employed for certain purposes in medicine. All the *varnishes* used by painters are of the class of gums or resins, properly prepared—such as copal, mastic, sandarac, lac, gum-lac, dragons' blood, &c. All are extremely inflammable, and great caution is necessary both in their preparation and general use.

Inks, either for writing or printing, are as much the result of chemical operations as paints or dyes. *Black ink* is a decoction of partly vegetable and partly metallic substances, the basis of the latter being iron. The ingredients commonly used are Aleppo galls in powder, logwood, gum-arabic, and sulphate of iron, in certain proportions; but latterly the art of manufacturing the article has been greatly improved, chiefly with the view of giving great fluidity as well as colour. *Blue ink* is either sulphate of indigo and tanno-gallate of iron; or, what is better, Prussian blue is dissolved in a solution of oxalic acid. *Red ink* is made by boiling two ounces of Brazil-wood in a pint of water, and adding some gum and alum. A better sort is manufactured from carmine, one of the colouring principles in cochineal, by the addition to it of ammonia.

Marking-ink, so universally used for marking linen, is a solution of nitrate of silver in water. The cloth is first damped with a solution of iodide of potassium, or even potash itself, allowed to dry, and the nitrate of silver solution written on. The silver is reduced, and appears black where such has taken place. The popular notion that this ink is indelible, or cannot be bleached, is far from the truth, as by the use of cyanide of potassium, the ink gets loosened from the cloth, and may be dissolved and washed out. A more certain and lasting marking-ink is that employed by bleachers to mark the cloth they receive from various manufacturers. This consists of a solution of tar in coal naphtha.

Printing-ink is quite a different substance from either of those mentioned, being a thick viscid body, resembling a black paint. Its ingredients are boiled linseed or nut-oil and lampblack, in the proportion of two and a half ounces of black to sixteen ounces of oil. The preparation of the oil is one of the most dangerous processes in the arts, and great care is required to prevent conflagration of the oleaginous material. There are various qualities of ink to suit different kinds of work. The prime object of attainment in making printing-ink, is to give it a deep black colour, which will endure after exposure on the pages of a book. Unless very great trouble be taken in grinding and mingling the materials in exact proportions, the ink, on being used, will gradually become brown, by the spreading of the oil. The French printing-inks are much superior to those made in Britain. *Indian ink* is used in China for writing with a brush, and for painting upon the soft flexible paper of Chinese manufacture. It is ascertained, as well from experiment as from information, that the cakes of this ink are made of lampblack and size, or animal glue, with the addition of perfumes, or other substances not essential to its quality as an ink. The fine soot from the flame of a lamp or candle, received by holding a plate over it, mixed with clean size from shreds of parchment or glove-leather not dyed, will make an ink equal to that imported. A variety of what are called *sympathetic* inks have been invented which might withstand all chemical obliterants. Some of these are made to remain invisible till some re-agent be applied, others require chemically prepared papers, and others, again, can be rendered visible or invisible at pleasure.

DYEING.

A remarkable circumstance connected with dyeing is the different degrees of facility with which animal and vegetable substances imbibe the colouring-matters applied to them. Tissues composed of the former, as silk and wool, receive more brilliant colours than those composed of the latter—as cotton and linen. The cause of this difference has not hitherto been discovered.

Although, in the most numerous class of cases, it is easy to impart colour to various tissues, yet when these become exposed to moisture, the dye-stuff is removed. It has therefore been found necessary to employ certain chemical substances which shall have the property of permanently fixing the colour upon the body which is dyed. These substances have obtained the name of *mordants* (from the Latin word *mordere*, to bite), because they were supposed at first, figuratively speaking, to bite the dye into the cloth. The same name has also been applied to those preparations which possess the property of altering the shade, or of heightening the colour, as it

is called. The latter, at the suggestion of Berthollet, are sometimes termed *alterants*. The action of the mordants in fixing the colour on the cloth is very decided. If a piece of calico be simply soaked with a solution of the colouring-matter of Brazil-wood, and thereafter washed, the whole of the dye can be washed out; but if the calico be first immersed in a solution of acetate of alumina (a mordant), and thereafter treated with Brazil-wood solution, it acquires a permanent red colour, which cannot be washed out. The principal mordants are—alumina employed in the form of a salt, as that of the acetate of alumina, and of alum; the oxides of tin, employed like the former in the shape of salts, which are prepared by dissolving tin in muriatic acid. Silk and woollen dyers, however, employ nitric acid or aqua-fortis for forming the salts of tin which they use. The salts of lead and copper are likewise had recourse to as mordants; and the gall-nut, which contains two very peculiar vegetable substances—tannin and gallic acid—is not only employed as a mordant, but also as a simple and powerful dye-stuff.

By varying the mordant, a great variety of shades may be derived from the same colouring-matter. Indeed, the mordant itself, in many instances, supplies a colour. For example, in dyeing with cochineal, when the aluminous mordant is employed, the colour produced is crimson; but when oxide of iron is substituted for the alumina, a black colour is the result. Cloth first treated with a mordant of acetate of alumina, and thereafter with a decoction of madder, Brazil and peach woods, comes up a *red;* with the same mordant and cochineal, a *pink;* with the same mordant and madder alone, a *lilac;* with the same mordant and quercitron and Persian berries, a *yellow.* With a very dilute solution of acetate of iron as a mordant, cloth becomes a *red* with madder; with stronger solution, a *purple* is produced; and a still stronger gives a *black. Chocolates* are procured by treating the cloth first with a mixture of the iron and alumina mordants, and thereafter dyeing with madder. *Yellows* are formed by immersing the cloth in solution of acetate of lead, and afterwards in solution of bichromate of potash. *Oranges* are readily produced by taking the cloth already dyed yellow, and boiling it in dilute milk of lime, or even washing-soda. *Browns* are formed by heating the cloth in solution of the sulphate of manganese, and passing it through caustic soda, and lastly placing it in solution of bleaching-powder.

When parts of the cloth are to remain uncoloured, it is necessary to print on a substance which destroys or throws off the colour. The *dischargers* in common use are not many. *Citric acid* is employed, mixed with gum, for the purpose of dissolving the alumina and iron mordants, and thereby unfitting those parts it is printed on from receiving a fixed or fast colour. *Tartaric acid* being printed on cloth, and the fabric then passed through solution of bleaching-powder, the acid sets free chlorine, which bleaches white the parts it adheres to. *Oxalic acid* discharges the iron mordant. *Protochloride of tin* discharges sesquioxide of manganese, and leaves a white instead of the brown. If the tin solution be previously mixed with Brazil-wood or cochineal, the brown of the manganese disappears, and a *pink* is left instead; mixed with logwood, the tin solution leaves a *purple*, and with Prussian blue, a *blue*. The yellows produced by acetate of lead and bichromate of potash are likewise discharged by protochloride of tin. The *protochloride of iron* sets free the manganese brown, and leaves an iron buff instead.

ETHER.

Ether is very closely connected with alcohol. Both contain a compound substance called ethyle—a compound of four equivalents of carbon, and five of hydrogen. Ether is built up of ethyle and one atom of oxygen, and is therefore the oxide of ethyle. Alcohol, on the other hand, is compounded of ethyle, an atom of oxygen, and an atom of water; and, strictly speaking, is the hydrate of the oxide of ethyle. Alcohol, therefore, differs from ether in containing an atom of water, which the latter has not; and, for practical purposes, the alcohol may be best regarded as made up of ether and water in a state of chemical combination. The substances employed in the preparation of ether are alcohol and sulphuric acid. The apparatus required is a capacious flask or retort attached to a good condenser (fig. 4). Two volumes of

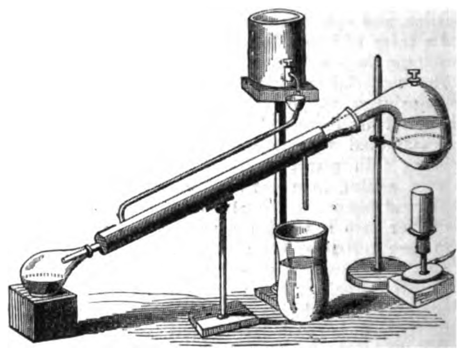


Fig. 4.

alcohol are first placed in the flask, and one volume of sulphuric acid is by degrees poured into the alcohol. The mixture must be well agitated, and thereafter heat applied. The chemical reaction which ensues is very complicated; but the result is, that the sulphuric acid so acts as to disunite the atom of water from the ether, which admits of both the ether and the water distilling over together in a condition of *mere mechanical mixture.* What comes away from the distilling apparatus is in one sense the same matter that was mixed with the sulphuric acid and introduced at first into the vessel to be heated; but now the chemical force which previously clasped that matter together has been overpowered, or otherwise directed by the sulphuric acid, and in consequence, the materials, ether and water, distil over, *mechanically mingled*, but not *chemically combined.* By the first distillation, the ether comes over contaminated with much water, and a little sulphurous and acetic acids. It is agitated with potash or lime till the upper layer of liquid, containing most of the ether, is not acid, which is then separated from the lower layer, and redistilled.

Ether is a colourless and transparent liquid, very mobile, with a very decided and characteristic taste and odour. Commercial specimens have a specific gravity at 60° F. of 740. Heated to 96° F., it boils, but it may be subjected to the most severe cold without freezing. Placed on the hand, it evaporates very rapidly, and leaves a sensation of cold. At ordinary temperatures, it readily evaporates from an open vessel, and forms a vapour with the great density of 2586, being 2½ times the density of common air. It is soluble in water to the extent of one volume in ten of water. It mixes with alcohol in all proportions; but on the addition of water, the alcohol is withdrawn, and the ether remains floating above. It is very inflammable, and burns with a yellow white flame. Mixed with air or with oxygen, and a light brought near, ether forms a most explosive compound. This property necessitates the employment of very perfect apparatus in the preparation of ether on the large scale, and, to avoid the chance of accidents, it is customary to have the opening to the fire on the outside of the building—the still in one room, and the receiver in another. Ether is useful as a solvent of fats and oils, as likewise of phosphorus. To the photographer it is of importance, as it furnishes

him with a liquid, which, in conjunction with alcohol, affords a ready means of dissolving gun-cotton and yielding collodion, so remarkable for the rapidity and accuracy with which it admits of sun-portraits being taken. Prior to the introduction of chloroform, ether was employed as an anæsthetic agent, but has been discontinued as such in so far as human subjects are concerned. It required a much larger quantity than chloroform, was not so expeditious in producing sleep, and left the patient more exhausted, and a prey to sickness, headache, and other after effects. Moreover, the combustibility and explosibility of ether rendered it much more dangerous to handle than chloroform.

GUM AND GUM-RESINS.

At one time the term *gum* was given to all exudations of plants, but now it is limited to a few, and from these all the gum-resins are excluded. The best example of a true gum is gum-arabic, which is exuded from a species of acacia growing in Arabia, India, Upper Egypt, and Senegal. The gum itself is of a white or yellow-white colour, and occurs in irregular masses with a conchoidal fracture. It is soluble in cold water, and in boiling water dissolves to the extent of 19 parts in every 100 of water. It is not soluble in alcohol or in ether. Gum is used in many processes: it is largely employed as a thickener of mordants and colours in dyeing, and of the various inks used for writing and printing. It is also used as a glaze or varnish, and to confer a gloss and stiffness to ribbons, linen, cotton, &c. When ground, it is often adulterated with starch, which may be detected by the production of a blue colour, when iodide of potassium and chlorine water are added.

British gum, *dextrine*, or *torrefied starch*, are terms applied to a gummy substance artificially prepared by heating ordinary starch. It is less expensive than true gum, and for the majority of purposes can be employed with advantage in its place. Unlike ordinary starch, it is quite soluble in cold water.

Gum tragacanth, or *gum-dragon*, is obtained from a species of astragalus growing in Asia Minor, Armenia, and Northern Persia. It differs from gum-arabic in not being completely soluble in water. The more modern views held on this subject represent it as composed of 50 per cent. arabine, 30 per cent. tragacanthine or bassorine, and 20 per cent. water and oxalate of lime. When bassorine is placed in cold water, it swells up into a kind of mucilage, but when boiled, it becomes entirely soluble. *Gum cerasine*, obtained from the cherry, plum, and almond trees, is identical with bassorine. In commerce, gum tragacanth occurs in white or yellow-white semi-transparent flakes, curled up, with much the appearance of horn.

Gum-resins are secretions from trees in warm climates. Many exude spontaneously, but an incision in the bark always expedites the process. When they pass from the tree, they are generally light-coloured liquids, but they soon solidify into a dark-coloured hard substance. They are composed partly of gum and partly of resin; hence they dissolve in part in water, and in part in absolute alcohol. A mixture of water and alcohol, as in *proof-spirit*, dissolves the gum-resins when heated over them: some gum-resins are popularly but erroneously named *balsams*, as they contain no benzoic acid.

GUNPOWDER AND GUN-COTTON.

The discovery of *gunpowder* rests in obscurity. The Chinese seem to have employed a coarse variety, about 200 years B.C. for fireworks, but not as a propelling agent. From China this impure gunpowder found its way to the Arabs, and they in their turn communicated the discovery to the Greeks. It is possible that gunpowder may have formed the principal ingredient in the *Greek fire*. The impure materials out of which the earlier specimens were manufactured only admitted of the comparatively slow combustion of the mixed mass; and it was not till the fourteenth century, when the ingredients were employed pure, that a gunpowder fit for being used as a projectile agent was manufactured.

The substances employed in the manufacture of gunpowder are nitre, charcoal, and sulphur. The exact proportions in which these ingredients are mixed differ according to the country, as also the use to which the powder is to be put; nevertheless, there is a great similarity between the various kinds of gunpowder, as will be noticed by comparing the figures in the following table, which gives the scale of proportion in 100 parts, adopted in different national and private gunpowder-works:

	Nitre.	Charcoal.	Sulphur.
Royal mills at Waltham Abbey,	75	15	10
French, for war,	75	12·5	12·5
" " sportsmen,	78	12	10
" " mining,	65	15	20
Chaptal's proportions,	77	14	9
Mr Napier's ditto.	80	15	5
United States of America,	75	12·5	12·5
Prussia,	75	13·5	11·5
Russia,	73·78	13·59	12·63
Austria,	72	17	16
Spain,	76·47	10·78	12·75
Sweden,	76	15	9
Switzerland,	76	14	10
China,	75·7	14·4	9·9

Saltpetre, nitre, or nitrate of potass, is abundant in nature, but may be also compounded by the artificial union of its two ingredients—nitric acid and potass. During the seventeenth century, before the importation of nitre from the East Indies commenced, the nitre required for gunpowder was procured by washing (lixiviating) the soil forming the floors of stables, pigeon-houses, and other outhouses. Special acts of parliament were granted to certain *saltpetre men*, whose business consisted in travelling through the country, and every now and again digging up clay-floors, putting the earthy matter in large tubs with water, agitating the mixture well, and thereafter boiling down the liquid, when a liquid nitre was obtained. Now-a-days, however, we derive our supply of that substance from the East Indies, where it is found on the surface of limestones, marls, and chalky strata, as likewise in the soil, being spontaneously generated there by electrical storms, and by the natural decay and putrefaction of vegetable and animal matter containing nitrogen. The slight silky tufts of the nitre are swept up with a broom, and are lixiviated, allowed to settle, evaporated, and crystallised. In this state it is exported; but the impurities which it contains require its subjection to successive solutions and crystallisations, ere it can be employed in the manufacture of gunpowder. The last process is that of fusion in iron pots at a regulated heat. It is tested by adding to its solution in distilled water nitrate of silver, with which it ought to occasion no perceptible milkiness.

Charcoal, as is mentioned in CHEMISTRY, is simply wood reduced to a charred condition (pure carbon), by being burnt to a kind of blackened cinder in a vessel closed from the atmosphere. For making gunpowder, light woods, such as the willow and alder, are the best, the pieces being stripped of their bark before being used. In preparing this kind of charcoal, it is important that the vapours be allowed freely to escape, otherwise the combustibility of the charcoal will be impaired. The preparation is usually effected in iron retorts over furnaces; and by a connecting-tube the vapour escapes, and is condensed into a tarry liquid, from which pyroligneous acid (acetic acid) and wood-spirit are afterwards extracted. When thus prepared, the charcoal is reduced to a fine powder.

Sulphur is procured in many volcanic countries, but the great emporium for it is Sicily. It can also be obtained from the metallic sulphurets, as from iron pyrites. At the gunpowder works it is purified for use

either by distillation or by fusion. In the first instance, the pure part is distilled over; and in the second, skimmed off, the impurities being left behind.

The three ingredients, charcoal, nitre, and sulphur, being duly prepared by trituration, and passed through fine sieves, are mixed and carried to a mill, where they are properly blended, by the pressure of a revolving stone on edge. The stone is of a calcareous quality, and goes round on a bedstone of the same nature. No metal or sandstone is employed either about the machinery or the mill-house, in order to avoid the danger of sparks. On this bedstone the composition is spread, and moistened with as small a quantity of water as will, in conjunction with the weight of the revolving stones, bring it into a proper body of *cake*, but not of *paste*. The line of contact of the edgestone is preceded by a scraper, which goes round with the wheel, continually scraping up the cake, and turning it into the track of the stone.

The proportions in which the ingredients are mingled are usually 77½ parts of nitre, 16 parts of charcoal, and 10½ parts of sulphur. This mixture is introduced into the bed of the mill in charges of forty-two pounds' weight, moistened with about two pounds of water. In summer, more water is required than in winter. After being three and a half hours in the mill, the *mill-cake*—as the gunpowder is now called—is taken out, and layers of it are placed between sheets of copper, and subjected to a pressure of seventy-five tons on every superficial foot, which serves to force the particles nearer each other, and gives a firmer and more compact mass. This is broken into small pieces by passing through two teethed rollers, or by being struck with wooden mallets; after which the graining is executed by placing these lumps in sieves, on each of which is laid a disk of lignum-vitæ. The sieves are made of perforated parchment or hair-cloth. Several such sieves are fixed in a frame, which, by proper machinery, has such a motion given to it as to make the lignum-vitæ runner in each sieve move round with considerable velocity, so as to break the lumps of the cake, and force the substance through the sieves, forming grains of several sizes. These granular particles are afterwards separated from the finer dust by proper sieves and reels. The corned powder is next hardened, and the rougher edges taken off, by being revolved in a close reel or cask turning rapidly on its axis. This vessel somewhat resembles a barrel-churn: it should be only half full at each operation, and has frequently square bars inside, parallel to its axis, to aid the polish by attrition. This glazing operation is often effected in a skeleton barrel lined with canvas in the interior, and revolved rapidly. Only the better varieties of gunpowder put on a gloss by simple attrition. The inferior varieties have such communicated to them by placing some black-lead in the barrel along with the grains of gunpowder. The result is, that the face of each gunpowder particle is rubbed bright on the same principle as housemaids rub the faces of their grates bright. The gunpowder is now dried, which is done generally by a steam-heat, or by transmitting a body of air, slightly heated in another chamber, over canvas shelves covered with the damp gunpowder.

The combustibility of gunpowder is too well known to require particular mention. When burned, it almost entirely becomes gas, one volume of gunpowder expanding to 787¼ volumes of cold air or gas; but as the vapours are much heated and expanded when they leave a rifle or a piece of ordnance, it is nearer the truth to say that one volume of gunpowder fired in a gun tends to expand to 2000 times its own bulk. It is the sudden creation of such a volume of gas that renders gunpowder of so much use in projecting bullets, balls, and shells, and in rending rocks and minerals in our mining operations. The enormous force of gunpowder may be noticed from the following experiments:—Count Rumford placed in a war-mortar one-twentieth of an ounce of gunpowder, and placed on the mouth of the mortar a cannon (24-pounder) weighing 8081 pounds. When the gunpowder was fired, the mortar was burst, and the weighty cannon was lifted up. Again, twenty-eight grains of gunpowder were enclosed in a cylindrical space, which they just filled, and when fired, the gas formed tore asunder a piece of iron which would have resisted a strain of 400,000 pounds.

White gunpowder is the name given to an explosive compound introduced two or three years ago, and intended to be a likely substitute for black gunpowder. It is prepared by carefully drying and pulverising in *separate* vessels two parts chlorate of potash, one part ferrocyanide of potassium (yellow prussiate of potash), and one part white sugar. When in a state of fine division, the three ingredients are to be cautiously mixed on a wooden platter with a wooden spatula, and immediately thereafter stored for after use. Great care must be taken not to resort to friction of any kind after the materials have been mixed. This precaution is necessary to avoid unlooked-for explosions. The white gunpowder is more explosive than gunpowder, and produces, when burned, amongst a host of other gases, a little hydrocyanic (prussic) acid gas. This property would render its employment dangerous to those in charge of a gun in a man-of-war or an ill-ventilated land-battery; and this fact, coupled with its being composed of more expensive materials than common gunpowder, has hindered its ever being employed on the large scale, even on trial. It may be noticed in passing, that the white gunpowder, besides being readily fired by a flame or red-hot iron, is likewise inflamed by a drop of concentrated sulphuric acid. This latter method of firing a similar compound was resorted to by the Russians in the infernal machines which they anchored so numerously in the Baltic Sea during the recent war. The concussion of a vessel coming against the machine was to have caused the acid enclosed within to spill on the explosive substance.

Gun-cotton.—Much interest and excitement was some years ago caused by the announcement of a substitute for gunpowder, which was said to be four times more powerful than that substance, weight for weight; to ignite at a much lower temperature; to be uninjured by water; and to burn without smell, smoke, or residue. This substance was the gun-cotton of Dr Schönbein, to whom the credit is due of discovering and making known the various useful purposes to which this remarkable body may be applied, although its actual discovery dates from a period prior to that when Schönbein published his experiments. Without entering upon either its history or its theoretical composition, as manifested in what are called xyloidine and pyroxyline, we shall merely advert to the plan adopted for the preparation of gun-cotton in the laboratory of the chemist—no minute description of its manufacture upon a commercial scale having yet been published. Well-cleansed cotton is immersed for several minutes in a mixture composed of equal parts* of the most concentrated nitric and sulphuric acids. The acid should then be pressed out, and the cotton, which remains impregnated with it, be well washed with water, until no acid reaction is perceptible to the tongue; it is now dried at a temperature below 212° Fahrenheit. Care should be taken in drying this substance to allow a free current of air to pass over it, and to spread out the cotton as much as possible, to prevent its forming into dense masses, which are said to be much more liable to explode. The temperature at which gun-cotton explodes is very various. At times, a specimen will resist, without exploding, a heat of nearly 400° Fahrenheit, whilst other samples explode much below 212°, the boiling-point of water. This difference in the exploding temperature led to the destruction of large works which were constructed in England for the manufacture of gun-cotton. Depending

* Schönbein recommends the use of three parts sulphuric acid, and one nitric acid of the specific gravity 1·5.

on the material not exploding at a water-bath heat, the drying-room was fitted up with hot-water pipes, but one of the first days on which the operations were proceeding, the gun-cotton in the drying-room exploded, and blew the manufactory to pieces.

When pressed in the hand, gun-cotton has a crepitating sound and feel, exactly resembling that heard and felt when one is kneading a snow-ball, at the time the snow is in the best condition for that purpose. On the continent, the gun-cotton is always dyed a particular purple tint, so as to lessen the chances of its being mistaken for ordinary cotton. It is very inflammable; so much so, that a little placed on the hand and set fire to, burns away so quickly that it does not hurt the hand. It is insoluble in water, hot and cold, and when plunged in water, removed, and dried, is found to have lost none of its original properties. It explodes violently when heated, or on ignition, leaving scarcely any residue, and creating very little smoke. The temperature at which it is thus decomposed is so much below that at which gunpowder explodes, that the cotton may be lightly placed upon the surface of gunpowder, and detonised by a red-hot wire without setting fire to the powder. Friction of the ordinary kind will not explode gun-cotton; but when placed on an anvil, and powerfully struck with a hammer, the heat generated by the stroke causes it to detonate. With reference to the projectile force of gun-cotton as compared with gunpowder, no authoritative statements have yet been made; but there appears reason to apprehend that its action in its present form is too rapid, and resembles too much that of fulminates, to render it applicable to the purposes of artillery. The gaseous products from its combustion are also such as cannot be altogether resisted by firearms, although, if air be absent, no great amount of corrosion can ensue; and as it has been found that gun-cotton impregnated with chlorate of potash or nitre has a still more powerful effect than that prepared in the usual way, the addition of these substances would at the same time tend to modify the corrosive action of the acid products of combustion. As a substitute for gunpowder in all mining and blasting operations, however, the superior local force of the cotton will be highly valuable; and it has indeed been found to effect as much as four times its weight of powder. Gun-cotton, like gunpowder, contains everything within itself requisite to its complete combustion; indeed, in the elementary composition of both, there is little or no difference.

The advantages which gun-cotton possesses over gunpowder are—1. One-fourth of the weight of material produces an equal effect, and hence a great saving in the carriage, in case the gun-cotton ever came to be largely used; 2. It burns completely away, and leaves no residue; hence there would be nothing left in the firearm to interfere with correct aim; 3. When it becomes wet or moist, it can be dried again, and is as good as ever; and 4. No smoke results from its combustion. Its disadvantages are—1. The great bulk that cotton, from its lightness, naturally assumes, which would render it necessary for a sportsman or soldier to carry a considerable-sized bundle instead of a small cartridge-box; 2. In its combustion much steam is developed, which would moisten the gun; 3. It explodes at such a low temperature that a gun repeatedly fired would quickly become so hot that the gun-cotton would take fire whenever it was rammed home;* 4. The production of nitrous acid fumes, which would tend to corrode the metal of the gun; and 5. Its price, which would be about four times that of ordinary gunpowder.

Loose cotton is not the only form in which woody fibre can be rendered explosive by the action of acids; the latter can resolve muslin cloth into *gun-muslin*, linen into *gun-linen*, tow into *gun-tow*, sawdust into *gun-sawdust*, and paper into *gun-paper*—all of which are more or less explosive.

The importance of gunpowder as an agent in blasting rocks cannot be overlooked. An ounce or two of powder, ingeniously directed, will detach more rock in an instant of time than a dozen of men will accomplish in a week. The general plan of operation is to bore a narrow hole two or three feet into the rock, pour in an inch or two of gunpowder, and plug the opening firmly, with the exception of a small canal or passage. This is filled with gunpowder, and the shot thereby fired. Vast quantities of building-stone, road-metal, coal, &c., are now dislodged by this force. Considerable danger undoubtedly attends the present system of firing the shots by the ordinary fuse; but if managers of such works could be brought to see fully the advantages of firing the charges by galvanic electricity, in place of the fuse, all danger would be avoided, and the employment of gunpowder as a blasting agent be rendered at once safe and practicable.

LEATHER.

Leather-making is the art by which the skins of animals are rendered impervious to the action of those external agents which would otherwise decompose them. This effect is brought about by steeping the skins in the astringent principle called *tannin* or *tannic acid*, when a chemical combination of the skin and tannin ensues, which is leather. This operation may be performed either with the hair on, or, as is generally the case, when it is taken off. Tannin is obtained from the bark of a number of trees, particularly the East India catechu, the common oak, the Spanish chestnut, the Leicester willow, &c. It is found in the largest quantities in catechu—one pound of this being equal to seven or eight pounds of oak-bark. Tannin is also obtained by a peculiar preparation from the gall-nuts of the Levant oak. When the bark of trees is to be used for tanning, it should be stripped from the trunk and branches in the spring, when the sap flows most freely. The trees should not be less than thirty years old, for it has been found that the bark possesses more tannin when old than when in a young state. The bark, when dried, is ground in a mill, to reduce it to a rough powder, after which it is ready to be used.

The first process which the skins undergo is steeping in lime and water of three or four different strengths, which is continued for a longer or shorter time, according as the skins are dry or fresh. Sometimes the skins are salted when they are imported from abroad; and in this case they require to be steeped in water, beaten, and rubbed, until they are brought to a fresh state. The hides are moved about or *handled* in the lime-and-water vats; and in the course of three weeks or so, the hair-sheath is decomposed, and the lime combines with the fat to form an insoluble soap. The horns are then cut off, and the skins put in heaps for a day or two, after which they are hung up in a shed. During this process, the slight putrefaction which takes place enables the hair on the one side, and the fleshy matter on the other, to be easily removed. This is done by a blunt knife, or scraper, the skins being stretched upon a wooden beam called the *horse*. The skins are then immersed for about forty-eight hours in water mixed with a little sulphuric acid, which has the effect of distending the fibres, causing the skins to swell. This process is called *raising*, and by it the tannin principle more easily reaches the inner fibres. When sufficiently raised, the skins are put into a pit with a layer of bark in the bottom. On this skins are laid, and then bark and skins alternately. The pit is filled up with a strong decoction of bark, and the whole is allowed to lie undisturbed for about six weeks. At the end of this time, it will be found that the tannin has become entirely exhausted; when the skins must be

* This is not mere speculation, as, at the siege of Mooltan, gun-cotton was tried, and whilst its propelling force was everything that could be desired, yet the gun soon got so warm as to render it advisable to cease firing.

taken out, and put again into the pit, along with fresh bark. In this they are allowed to lie for three months; and the process is repeated two or three times, according to the quality of the leather required. From six to eight months in all are sufficient to complete the tanning of the commonest kind of sole-leather, called *crop* by the trade; but for the better kinds of sole-leather, from a year to a year and a half will be required. *Bend-leather* is the strongest of all sole-leather, and in manufacturing it, the tanning process is continued for a longer period than is necessary for crop. The best and thickest skins also are selected for this kind. When properly tanned, crop-leather is hung up in an airy house to dry, which is performed slowly, and the article is then fit for the market. Bend-leather, after being dried, is beaten into a firm consistence, so that when cut, the edges present a glossy appearance. The instrument with which bend-leather is beaten is a broad brass hammer; and this kind of leather may be easily distinguished from its being darker in the colour, in consequence of lying longer in the tannin. A coarse kind of upper leather is also made from cow-hides, the weakest and thinnest being selected for this purpose. The skins of seals, calves, &c., are manufactured into upper leather.

Several improvements have recently been made in the manufacture of leather, by which the tannin principle is more readily admitted to the inner fibres of the skins. One of the improved methods consists in using a machine of two rollers, which is placed in the middle between two tan-pits. The hides having been previously divested of the hair, &c., are fastened together, and put into the tan-pit in regular folds. After lying in this for a certain time, the end of the belt of hides is laid upon the under roller, which, being set in motion, carries the belt over to the other tan-pit. This is done without pressure; but when the hides have become soft, the upper roller is pressed down against the under one. The hides are again passed through between the rollers, which press out the exhausted tannin, and prepare them for being submitted to a fresh infusion. More recent improvements are those of Mr John Cox of Gorgie Mills, near Edinburgh, for which he has obtained patents. His great object is to force the liquid tannin into the vesicles of the skin, which is sewed into the form of a bag, and immersed in tanning liquor, while the interior is also filled and compressed from a supply of liquor through a pipe from a cistern placed a few feet above the pit. Dr Turnbull of London has likewise patented a very ingenious process, depending upon the principles of *endosmose* and *exosmose;* and another, in which the forcing-pump is employed to expedite the impregnation of the hide with the tanning liquid. The theory of endosmose and exosmose teaches us that when two fluids of unequal density are separated by a membrane, the heavier fluid will attract the lighter through that membrane. Upon this principle, the skins are sewed up in the form of bags filled with a super-saturated solution of tannin, and placed in a reservoir filled with a sub-saturated solution—or *vice versâ*—upon which the permeation goes on with rapidity.

Skins intended for the *manufacture of gloves* require in the first place to be washed with pure water, and immediately after being washed, the skins must be worked, or they are liable to become marked with indelible spots. They are now rubbed upon a convex beam, and the rough parts removed with the fleshing-knife. The fleshy sides of the skins are covered with a cream of lime, and piled together with the wool sides of each pair outermost. They are left in this state for from four to six days, or until the wool is found to come easily off. The skins are then washed in a running water, to free them from the lime, and the wool is taken off by means of small spring tweezers. After this, they are fleeced smooth by a rolling-pin, or by rubbing with a whetstone.

The next operation is steeping the skins in a strong solution of lime, for the purpose of swelling and softening them. They are now put into weak lime-water, and drained upon inclined tables, which is repeated several times, the process occupying about three weeks. The outsides are then rubbed with a whetstone, to remove any wool which may still remain; after which, the skins are fit for what is called *branning.* Into twenty gallons of water, forty pounds of bran are put, and the skins are steeped in this mixture until they sink, which they will generally do in about two days in summer, and eight in winter. During the branning process, the skins must be frequently stirred, that each may get a due share of the liquid. They are next steeped in a solution of alum and sea-salt, which is called the *white stuff.* From twelve to eighteen pounds of alum, and about three pounds of salt, are put into a copper with twelve gallons of water. This mixture is dissolved by heating the copper; and when about to boil, three gallons of the solution are poured into a basin, in which twenty-six skins are worked one after another. The twelve gallons are thought sufficient for one hundred skins; and when all have been worked, they are allowed to steep for about ten minutes. The skins are then taken out, and fifteen pounds of wheat-flour are added to the solution. This is next run out of the copper vessel, and the yolks of fifty eggs put into it, in which the skins are worked, and afterwards allowed to steep for a day. They are then taken out, stretched upon poles, and allowed to dry. By this operation, the leather is rendered very white and soft, which enables it to bear the working of the softening-iron. This consists of a plate of iron about a foot broad, mounted upon an upright beam thirty inches high, which is fixed to the end of a plank three and a half feet long. This plank is heavily loaded; and the skins having been previously wetted, are rubbed with the iron upon a board. The skins are sometimes stretched upon the horse, and well rubbed with a blunt two-edged knife, and afterwards polished with pumice-stone. They are then worked upon the stretching-iron, and afterwards smoothed with a hot iron. Sheep-skins are frequently dressed for household purposes, and on this account are technically called *housings.* For this purpose, those skins are selected which have the longest and most beautiful fleece.

Chamois leather is prepared by washing, steeping in lime-water, taking off the fleece, and then branning the skins as before described. The outer skin, or epidermis, is next cut off upon the horse, which removes all excrescences, and renders the skins equal in thickness. They are then branned for a short time, and well beat in a fulling-mill. The skins are afterwards oiled; subjected to a fermenting process; washed in potash lye, and dried. The very thick and firm, but pliable sort of leather, called *buff* (originally made from the hide of the urus, or wild bull of the forests of Poland, Hungary, and Russia, but now also from cow-hides), is dressed in oil, and prepared much in the same way as chamois.

Morocco or *Turkey leather* is manufactured from goat-skin, but a spurious article is frequently sold under this name, which is made from sheep-skin. The process is much the same as for glove-leather, except that the washing is performed oftener, and the skins are salted previous to being dyed. Morocco leather is dyed with cochineal, about an ounce being required for each skin. The cochineal gives a scarlet colour to morocco leather; but other colours may be given to it, such as black, by using the red acetate of iron; blue, by indigo; yellow, from the roots of the barberry. The skin is next tanned in a decoction of sumach. The tanning is performed twice, the process requiring about twenty-four hours. The skins are then rubbed hard with a copper blade, and hung up to dry.

Russia leather, well known for its durable properties, is prepared by steeping in alkaline lye, and then in

dogs' dung; after which it is fulled and tanned with birch-bark. It is generally dyed of a pale-orange colour, is roughened in the surface by an iron tool, and receives its peculiar odour from being rubbed with the empyreumatic oil of birch. *Maroquin*, commonly of a red or yellow colour, is another Russian leather similarly prepared. *Shagreen*, brought chiefly from Astrakhan, is prepared from the strong skin which covers the crupper of the horse or ass. Its peculiar granulated surface is produced by treading small round seeds into the skin when soft; these are afterwards removed, the leather dyed green, and the surface worked down by rasping, when it finally presents the appearance of white dots on a green ground.

Currying is the process by which the newly tanned rough leather is converted into the soft, flexible, and jet-coloured article from which the upper leathers of shoes are made. The currier first steeps the leather, and placing it upon a piece of basket-work, beats it with a mallet, in order to soften it. By means of scraping and paring with knives of a variety of shapes and degrees of sharpness, the inequalities of the surface are now removed, and the uniformity of the texture improved. The leather is then pommelled by an instrument grooved on the under side, and with a cross strap on the top, under which the hand of the workman goes. The leather is folded with its grain side in contact, and rubbed strongly with the pommel, which gives it a granular appearance and greater flexibility. It is then conveyed to the drying-house, where grease is applied to soften it. The grease employed is a mixture of tallow and cod-oil, called *dubbing*, and is applied to the leather by means of hard brushes upon a large broad table. When well greased, the leather is hung up to dry, in order that it may thoroughly imbibe the oily matter; and afterwards it is well scraped, to free it from all superfluous oil, which would otherwise injure its appearance, and prevent it from receiving the colour readily. The leather is now rubbed on the flesh side with a brush dipped in a composition of oil and lamp-black, until it is thoroughly black. It is then black-sized with a brush or sponge, rubbed again with the oily matter, and afterwards scraped with glass. When coloured (that is, blacked) upon the grain side, a solution of sulphate of iron or copperas is employed. The leather is then wetted with stale urine, and afterwards rubbed with an iron, to render the grain as fine as possible. The bright shining varnish now common on dress-boots is called *enamelling*.

Cow-hides, when dressed for upper leather, are called *neat's* leather, and the shoes made from it are coarse. Common shoes are in general made from calf-skin, which is prepared in the same manner. The uppers of boots are all made from calf-skin, the best part for this purpose being the back and flank. This also applies to cow-skin leather. A considerable number of shoes are made from a description of leather called *kip*, which is prepared from the hides of young cattle, and is consequently intermediate in quality between calf-skin and cow-hide. Horses' hides were formerly much used for making leather, generally known as *cordovan;* but they are now almost entirely superseded by cow-hides, which are greatly preferred.

Parchment is prepared chiefly from the skins of sheep and she-goats. The skins are steeped in the lime-pit, deprived of their wool, and stretched tightly on a wooden frame, where they are repeatedly scraped and ground with fine lime and pumice-stone, and then allowed to dry, still in the state of tension. After drying, they undergo a second set of manipulations, in order still further to equalise the thickness and smooth them. *Vellum* is a finer kind of parchment, made from the skins of calves, kids, and young lambs. Pigs' skins are prepared in this way for covering church-books. For drum-heads, sieves, battledores, &c., skins of goats, calves, wolves, asses, &c., are used.

NAPHTHA.

In many parts of the world, but especially in Trinidad, a vast quantity of a black substance, *asphaltum*, is found. In general, it is a thick, viscid, and even hard mass; but occasionally soft and even liquid portions are observed, which owe their fluidity to the presence of *naphtha* and *petroleum*. The great source, however, of naphtha is the destructive distillation of coal. In the coal-gas works, there are evolved from the retorts, besides the gas itself, certain vapours, which become liquid as they pass through the *coolers* or *condensers*, and these consist of *naphtha*, *tar*, *ammonia*, and *water*. When this mixture is allowed to settle, the ammonia and water sink to the lower part of the lake or vessel, and the tar dissolved in the naphtha, floats above. The upper liquid being drawn off, and introduced into a retort, is distilled, and the first portions which come over are composed essentially of naphtha. The variety of coal which yields naphtha in largest quantity is the famous Boghead coal, which can be so distilled in a retort as to evolve little or no gas, but pass off entirely as naphtha and true oil. (See Oils.)

When rectified, naphtha has a specific gravity of 750 to 820. It burns readily with a smoky flame, and possesses great illuminating powers. It is accordingly employed as a source of light; and when the lamp is so constructed that the liquid is heated, and the vapour is driven out to be consumed, it produces perhaps the most brilliant and dazzling light in common use. It is not soluble in water, but readily mixes and dissolves in absolute alcohol, ether, and the essential and fixed oils. It boils at a temperature ranging between 320° and 365°. It is extensively used in the preparation of the cheaper varnishes, as also for dissolving caoutchouc in the manufacture of water-proof cloth.

Naphthaline is a substance somewhat resembling naphtha, and obtained as a solid crystalline matter, during the distillation of naphtha from coal-tar. It fuses at 176°, and boils at 413°. In its combustibility and solubility, it much resembles ordinary naphtha.

OILS AND FATS.

There are two distinct classes of oils—namely, the *essential* or *volatile* oils, and the *fixed* or *non-volatile*. As these differ widely in their properties, it will be better to consider them separately.

1. Essential or Volatile Oils.

These are the odorous principles of plants, which in some instances, as in those of the orange and lemon peel, can be squeezed out. When placed on paper, they evaporate, and do not leave a greasy stain. The best examples of the class are turpentine and camphor. *Turpentine* is obtained from trees of the fir-tribe, and its collection is carried on to a large extent in America. The bark of the tree is cut in spring, when the juices are in active motion, and a thick treacly mass exudes, which is common turpentine. When this is placed along with water in a still, and heated, the water begins to boil, and the steam rising up through the upper stratum of common turpentine, carries away the volatile principle contained therein, and leaves behind the fixed matter, which is common resin. The product of distillation, collected in a cooled receiver, consists of two layers of liquid, the upper one of ordinary spirits of turpentine, and the lower one water. The upper stratum can be siphoned off, and constitutes the turpentine of commerce. When the exudation from the cut surface of the tree is allowed to dry on the tree, and thereafter purified by fusion, it hardens into *Burgundy pitch* or *cobblers' wax*. Rectified turpentine is a clear liquid, with a hot taste and peculiar odour. It is insoluble in water, and is very inflammable, burning with a sooty flame. It is much used in the manufacture of varnishes, and the many kinds of furniture-polish, as also by the

painter in oil-colours, who, under the name of *turps*, mixes it with the oil-paint, in order to hasten the drying.

Camphor is obtained from the *camphor laurel*, a plant growing in China and Japan. The wood of the roots, stem, and branches, is chopped up into fragments, and thrown into a boiler containing cold water. The head of the boiler is made of earth, and contains straw. When the water is heated, the steam carries off the camphor, which is deposited in coarse particles, like raw sugar, on the straw. These impure grains are placed in a glass flask, nearly spherical, with a small opening at the upper part. Heat is cautiously applied; the last traces of water accompanying the crystals are allowed to escape, when the opening is closed, and the camphor vapour slowly sublimes from the lower part of the flask, and accumulates in the upper cool half. When the operation is finished, the flask is broken, and the cake of purified camphor taken out. Camphor is a white, semi-transparent solid, with a fragrant odour, an index of its volatility. It is very inflammable, and is so light that it floats in water, and may even then be set fire to. It is not soluble in water, but is readily dissolved by alcohol, &c.

The other odoriferous and volatile oils agree in their mode of manufacture with that pursued in the preparation of turpentine and camphor.

Oil of cinnamon is procured from cinnamon, the bark of the cinnamon-tree growing in Ceylon; *oil of cloves*, from cloves, the unopened flowers of the clove-tree, found in the Moluccas; *oil of lavender*, from the common lavender plant, extensively grown in Surrey in England; *oil of nutmegs*, from nutmegs, the fruit of the nutmeg-tree, cultivated in the Moluccas, Sumatra, Java, &c.; *oil of peppermint*, from the dried peppermint plant common in Britain; and the oils of *bergamot*, *aniseed*, *caraway*, *cassia*, *chamomile*, *copaiva*, *dill*, *juniper*, *lemon-peel*, *marjoram*, *orange-peel*, *penny-royal*, *rosemary*, *rue*, *sassafras*, and *spearmint*, from the respective plants, or portions of plants, which contain them.

2. Fixed or Non-volatile Oils.

This division includes those oils which have no power of volatilising at a water-bath heat, and which leave a fixed greasy stain on paper, when they fall on such. They may be liquid or solid; the property of fluidity or solidity being the result of the mere application of heat or cold, does not chemically alter the constitution of the particular oil. Palm-oil in this country is solid, having the consistence of butter; but in Africa it is liquid. Olive-oil is liquid here, but in the arctic regions it is a solid; and the same remark applies to tallow, hog's lard, coco-nut oil, &c. The same property is observable in water, which may be liquid in temperate regions, solid at the poles, and gaseous in our kettles or steam-boilers, but is still the same substance, water.

Olive-oil is obtained from the fruit of the olive-tree, which is cultivated extensively in Italy, and to a less extent in Syria, Palestine, Greece, &c. The fruit is bruised and subjected to great pressure. The oil at once flows away, and the finer varieties are sent into the market as *virgin salad oil*. Much of the oil remains with the vegetable albumen of the fruit, and cannot be extracted by pressure. It comes away, however, when hot water is added, and the pressure renewed. The oil which is thus obtained is known as *Gallipoli oil* and *Florence oil*, and is not such a fine pure oil as that obtained by pressure alone.

Coco-nut oil is manufactured from the kernel of the nut of the coco-nut tree, which grows wild near the coast of all tropical countries, especially in Brazil. The operation consists in detaching the husk from the nut, which is then broken, and after drying, is exposed to compression, or ground in a mill. In tropical regions, the oil is liquid, but in this country, excepting a few days in summer, it is solid. This oil is used in lamps in Ceylon, and many natives anoint their bodies with it. It is much used in this country in the preparation of soap, and even of candles, and forms a good substitute for olive-oil in the formation of ointments, plasters, &c. When heated, and resin added, a material is produced which does well for filling in the seams of ships, and for preserving corks of bottles from the ravages of insects.

Palm-oil is obtained from the oil-palm growing on the western coast of Africa, south of Fernando Po. The fruit of this palm is about the size and shape of a pigeon's egg, and has a yellow colour. On being bruised into a pasty consistence, and treated with hot water, the oil rises and floats on the surface of the water, where it congeals as it cools. As brought to this country, the oil has a more or less yellow colour, a sweet taste, and a pleasant odour. It melts between 80° and 100°. It is principally composed of a white solid substance called *palmitine*, which is itself compounded of palmitic acid and glycerine. Palm-oil is most extensively employed in the preparation of composite candles. It can readily be bleached white by exposure to air, or by the action of bichromate of potash and sulphuric acid.

Almond-oil, *castor-oil*, *linseed-oil*, *poppy-oil*, &c., are manufactured in an analogous manner from the seeds or fruits of the plants in which they are naturally contained.

Animal oils require little notice. *Butter* is the oil peculiar to the milk of the mammalia. *Tallow* is a generic title, comprehending the fat of many animals, including the ox and the sheep. *Mutton suet* is restricted to the fat of sheep, and *beef suet* to the fat of oxen. *Lard* is the fat of the pig.

With few exceptions, the oils, vegetable and animal, are composed of *oleine*, *margarine*, and *stearine;* and these respectively contain *oleic*, *margaric*, and *stearic acids*, in chemical combination with a sweet principle named *glycerine*.

The uses to which oil may be put are multitudinous. Some of these have been referred to, others remain to be noticed. As a lighting agent, *train-oil* and *sperm-oil*, both from the whale tribe, are employed. *Sweet-oil*, procured from rape-seeds, supplies a good lubricating agent. *Cod-liver oil*, extracted from the liver of the cod-fish, affords a valuable medicinal agent. *Olive-oil* is much prized for culinary purposes. *Linseed-oil*, when boiled, is largely used in the manufacture of oil-paints; whilst all the oils and fats, without exception, form more or less useful soaps, when boiled with water and an alkali.

Recently, a new source of oil has been discovered. The Boghead coal, when distilled at a comparatively low temperature, yields much liquid matter and little gas. The liquid can be separated into (1) an oil, valuable as a lubricating agent; (2) an oil, rivalling sperm-oil in readiness and brilliancy of combustion, and in affording a smokeless and odourless source of light; (3) a solid substance, called paraffine, capable of being manufactured into first-class candles; and (4) a naphtha of the finest quality, much prized for illuminating purposes, and for dissolving resins to make varnishes.

SOAP.

This exceedingly useful article, of which the ancients were entirely ignorant, is a compound of certain ingredients in oils, fats, or resin, with a salifiable base. If this base be potash or soda, the compound is used as a detergent in washing clothes. When an alkaline earth or oxide of a common metal, such as lead, whose oxide is litharge, &c., is the base, the compound is insoluble in water. The insoluble compounds, however, are very little used, except in some few cases of medical treatment. Animal fat, grease, or tallow, as it is variously termed, is a compound of a solid substance called, in chemistry, *stearine*, and of an oil called *oleine*, the basis of which is carbon, with a little hydrogen and oxygen. On subjecting tallow to a hot lye of soda (or potash), a

chemical change takes place in the constituents, and we have the material named *margaric acid*, and a fluid, *oleic acid*, and together they enter into a saline combination with the alkali. The result, a soapy substance, is thus said to be a union of margarate of soda and oleate of soda. Saponification also takes place with vegetable fats and oils, which are now largely employed in commerce.

Common *hard white soap* is made chiefly from soda and tallow. The soda was at one time extracted from kelp, which was made by reducing certain kinds of sea-weed to ashes by burning; the result in soluble material is a crude alkali, consisting mainly of carbonate, sulphate, and muriate of soda and potash. It was manufactured in large quantities on the shores of the Western Isles of Scotland and Ireland; but has latterly been disused, in consequence of the substitution of barilla, and especially of soda-ash from the decomposition of sea-salt. This branch of manufacture—the conversion of common salt into common soda—is now carried on to a very large extent. The solution of soda is now generally prepared by dissolving common soda in water, and adding thereto slaked lime—the supernatant liquid is diluted with water to the required strength, and constitutes the lyes used in the soap-manufacture. A quantity of lye, not well defined, but known by experience, is poured on the melted tallow, and the mixture is boiled, a workman agitating the materials to facilitate the combination. The fire being withdrawn, and the aqueous liquid having subsided, it is pumped off, and a new portion is thrown in. A second boil is given; and so on in succession. Two or three boils are performed every twelve hours, for six days—constituting twelve or eighteen operations in the whole. Towards the last, the stronger lye is brought into play. Whenever the workman perceives the saponification perfect, the process is stopped, and the matters are allowed to settle. The impurities are deposited in the pan, which, from their colour, are called *niger*, and the scum is taken off. After standing some days, the soap is lifted out, poured into the moulds, and afterwards cut into bars.

Though tallow is the principal oil employed in the manufacture of *white soap*, yet, when the price will admit of it, lard is added to the extent of 50 per cent. or more, which gives the soap a fine 'smooth skin.' Coco-nut oil is also added occasionally to the extent of 10 per cent.

Yellow or *resin* soap is prepared in a similar manner as that detailed above—from tallow, resin, and soda. For this kind of soap, beef-tallow is generally employed, as the yellow tint which it possesses renders it not so useful for preparing white soap, for which the purer and whiter mutton-tallow is retained. In the manufacture of yellow soap 100 parts of tallow are mixed with 20 parts resin, the alkaline lye added, and heat applied. After repeated boilings with fresh lye, other 20 parts of resin are added, and the boilings again resumed. After six days, the mixture is allowed to settle, the *niger* separates, and the soap is put into frames, and cut into bars as usual.

Mottled, *marled*, or *speckled* soap, which is now a favourite in the north of Scotland, is resin soap which has not been permitted to deposit its *niger*, and therefore still retains its impurities, which are the cause of its peculiar appearance.

The compounds of tallow or oils with potash (derived from the ashes of land-plants) remain of a soft consistency, and form what are termed *soft soaps*, useful in scouring. We can only afford space for an account of the process of manufacturing one of the common kinds of soft soap, as lately practised by an eminent soap-boiler near Glasgow. Whale or cod oil, to the amount of 273 gallons, is put into a boiler, along with four hundredweights of tallow, and 252 gallons of potash lye. On heat being applied, the mixture froths up very much, but means are adopted to prevent its boiling over. There are then added at intervals fourteen measures of stronger lye, each measure holding twenty-one gallons. After suitable boiling without agitation, the soap is formed, amounting in all to one hundred firkins of sixty-four pounds each from the above quantity of materials. The manufacturer is not particular as to the oil employed in this soap. Any refuse olive, linseed, or other oils, as well as the *niger* of the better soaps, are thrown into the pan. The peculiar spotted appearance which the *soft economical* or *black soap* presents, is formed in it after standing some weeks. The *figging*, as it is called, is supposed to be a spurious form of crystallisation.

Toilet soaps are either made from common white soap, or from purified hog's lard, with the addition of olive, almond, palm, coco-nut, and other oils. These, when prepared, are perfumed with various scents. The soap is cut into thin shavings with a plane, and melted in a pan placed within a hot water or steam bath. When melted, the colouring-matter and perfume are added, which generally consist of vermilion for bright red, *ochre* for dull red, *saffron* for light yellow, *Prussian blue* for blue, and *Spanish brown* for brown, such as that of Windsor soap; accompanied by the scent, which may be the *essence of bergamot*, *musk*, *orange-blossom*, *cinnamon*, *&c.*

Castile soap, or *Spanish* soap, is prepared from olive-oil and alkaline lye.

Certain soaps contain admixtures of certain detergent mineral substances, as silica, alumina, soap-stone, porcelain-earth, and fuller's-earth. The firmness of the soap is not diminished by the addition of such substances, which exert, however, a purely mechanical action, and are contained in no kind of chemical combination. The value of the article so manufactured is very much reduced, as a great portion of the real soap is replaced by a substance of similar, but inferior efficacy, and whose price bears no comparison with that of the fats. *Sand soap*, for example, is one of those recent manufactures, and contains from 60 to 70 per cent. of pure sand; *pumice soap* is another, containing from 20 to 30 per cent. of silicious matter; and *silica soap*, perhaps the best of them, about 20 per cent. of insoluble residue. *Chlorine soaps* are preparations intended to realise the idea of the union of the detergent properties of soap with the bleaching effects of the compounds of chlorine. It is almost unnecessary to remark that such a union is impracticable; and these chlorine soaps, in the words of a high authority, 'are nothing more than foolish novelties.'

PYROTECHNY.

The class of combustibles in the manufacture of which a knowledge of chemistry is more particularly required, includes gunpowder, gun-cotton, fulminating powders, the material of Congreve and sky rockets, bomb-shells, percussion-caps, rapidly igniting matches, and of fireworks generally. The term *pyrotechny* (from *pyr*, fire, and *technê*, art) has been applied to the art of making and compounding these substances.

The leading ingredients in most explosive combustibles are charcoal, saltpetre or nitre, and sulphur. In making fireworks of a varied kind, however, numerous other substances are employed. The chief are chlorate of potass, fulminating silver, and mercury, preparations of steel, copper, and other metals, with various oils, spirits, and resins.

Rockets.—The common modern rockets, which are generally employed as signals or tokens of rejoicing, may be described as tubular cartridges of paper, pasteboard, wood, or metal, filled with combustible substances, which, on ignition, cause the cartridge to shoot rapidly through the air. The principle on which rockets rise in the air is simple, and may be explained here, once for all, as it applies to all varieties of flying fireworks. A vessel containing a fluid which tends to expand, will be motionless so long as the vessel

is closed on all sides, because the pressure is then equal everywhere; but if an opening is made, the pressure will not be equal, and the vessel will then tend to move towards the side on which the whole pressure still remains. If the opening be below, the tendency will be to rise; and if the expansive force be great enough, and the vessel sufficiently light, the vessel will obey the pressure and ascend. When the expansive force is exhausted, it will again descend, by the ordinary influence of gravitation. In the case of the rocket, the combustion commencing below, creates the expansive gas, and the pressure forces the rocket upwards. The rocket moves upwards from the same cause that makes a musket move backwards when fired; only that the recoil of the rocket is continuous, because the explosion is continuous. The cartridge or tube, commonly of pasteboard or pasted paper, must be very strongly formed, if large, and intended to ascend high. The charge of sky-rockets varies according to the bore of the cartridge. Nitre 16, sulphur 4, and charcoal 7, are the contents and proportions of the charge when the bore is three-fourths of an inch; and the charcoal is merely increased a very little when the bore is enlarged. The composition is such that it does not explode all at once, but consumes gradually. This is the common rocket, with the usual light of gunpowder. When a rocket with a *brilliant* light is wanted, three parts of fine steel-filings are added; and when the light called *Chinese-fire* is desired, three parts of fine borings of cast iron form the addition to the three ingredients first mentioned.

The *garniture* of a rocket, as the crackers, showers of fire, stars, serpents, &c., are called which are commonly attached to it, with what is termed the *pot*, are of course added before igniting the charge in the central tube or fusee. 'The pot is a pasteboard tube, wider than the body of the rocket, and one-third of its length. After being strangled at the bottom like the mouth of a phial, it is attached to the end of the fusee by means of twine and paste: these are afterwards covered with paper. The garniture is introduced by the neck, and a paper plug is laid over it. The whole—for still greater strengthening—is enclosed within a tube of pasteboard terminating in a cone, which is firmly pasted to the pot. The quick-match is now finally inserted into the *fusee* or *soul* of the rocket, and a light rod or stick attached to the end of the whole, to keep it in a perpendicular ascent.' The beauty of the rocket depends much on the style of the garniture. These, whether stars or serpents, are charged fusees, stronger or weaker, formed into the shape wanted, and giving kinds of light modified by the ingredients. Stars which give golden showers are formed of nitre, 10; sulphur, 10; charcoal, 4; gunpowder, 16; lampblack, 2. *Petards* are sealed cartridges, which burst in the air; and *crackers* are square boxes of pasteboard, hooped and charged with gunpowder. But the finest accompaniment of the rocket is the Roman candle, which is a fusee so formed as to throw out in succession, as the combustion reaches them, very fine stars. These stars are small cylindrical masses of nitre, sulphur, and gunpowder, steeped in spirits and gum.

Congreve rockets, first used in the attack of Boulogne, 1806, are of various dimensions, and are differently armed as they are intended for the field or for bombardment. Those of the first sort carry shells or case-shot; the others are armed with a very combustible material, and are called *carcass rockets*. Their form is cylindrical, and they are composed of strong metallic cases. The sticks employed for regulating their flight are of different lengths, according to the size of the rocket. The carcass rockets are armed with strong iron conical heads, pierced with holes, and containing a substance as hard and solid as iron itself, which, when once inflamed, is inextinguishable, and scatters its burning particles in every direction. When this substance is consumed, the ball explodes like a grenade. The rocket is projected horizontally, and whizzes loudly as it flies through the air.

Bomb-shells are spherical cases of metal, fitted to be discharged by cannon, and containing a central charge of gunpowder, with an external charge of substances fitted to spread and inflict injury on the explosion of the powder, which is ignited by a fusee. The bombs also spread combustion where they alight.

Of *fixed fireworks*, or those whose motion is confined to a spot, jets, wheels, suns, trees, lances, spirals, revolving suns, double or Catherine wheels (two suns in one axis, revolving opposite ways), and many other beautiful contrivances, are now common exhibitions. In all preparations of a pyrotechnic nature, nitre, sulphur, charcoal, and gunpowder, are the chief ingredients. By means of spirits, gums, resins, and oils, the quality and duration of the light are modified, and the principal articles of that description in use are alcohol, bitumen, camphor, wax, turpentine, lard, and the like. Again, the colour of the fire, on which so much of the splendour rests, is modified by employing other articles. Copper-filings and sal-ammoniac give a greenish tint to flame; zinc, a fine blue; amber, and very dry common salt, a yellow; lampblack produces a deep red with gunpowder, and a pink with nitre in excess; camphor gives a fine white; lycopodium gives a rose colour; and sulphate of strontia, a beautiful purple light.

Instantaneous Matches, commonly known as *Lucifers*, are nearly all made of one substance—the chlorate or oxymuriate of potass. Dr Ure's formula for making the matches is as follows:—Thirty parts of the chlorate, in fine powder, are to be mixed gently with a knife upon paper with ten parts of very fine sulphur, eight of sugar, five of powdered gum-arabic, and enough of powdered vermilion to give a rose-tint to the whole. The chlorate, gum, sugar, and vermilion are then gently but well mixed, after which as much water as will make a thin paste is added, and then the sulphur is thoroughly mixed with the whole.

Of the numerous *fulminating powders* known to chemists, none, comparatively speaking, has any economical importance, except the fulminate of mercury, which is used for *percussion-locks*. The formula for the manufacture of the fulminate is as follows:—Dissolve 100 parts of mercury in 1000 parts of nitric acid, and add the solution to 830 parts of alcohol, a large vessel being used. A gas rises, which must be allowed to escape, and at a distance from flame. When the effervescence ceases, the contents of the vessel are to be poured out on a large double paper filter in a glass funnel, and cold water thrown over it till the drainings no longer redden litmus paper. The powder adhering to the vessel is also to be placed on the filter, with a little water. The superfluous acid thus washed away, the powder of fulminate of mercury, adhering to the filter, is lifted away, and opened out on plated copper or stoneware heated by steam. The powder, when dried, is in the form of small gray crystals, and is then to be packed in small parcels, and kept close from the air in bottles or boxes. Two and a half pounds of the fulminate will charge 40,000 percussion-caps. The preparation consists in grinding the fulminate upon marble with 30 per cent. of water, adding six parts of gunpowder for every ten of the fulminate. A dough is obtained which, when dried in the air, is introduced in small fixed portions into the bottom of the percussion-caps.

FICTILE MANUFACTURES.

WE employ the term *fictile* (*fingo*, *fictum*, to fashion) to comprehend all those arts which, like that of the potter, involve the moulding or fashioning of crude materials into determinate forms. Thus, with some degree of latitude, earthenware, porcelain, glass, bricks, tiles, mosaic tesseræ, cements, artificial gems, and the like, may be designated FICTILE FABRICS, in contradistinction to those of woollen, linen, silk, cotton, and other vegetable and animal fibre, which are strictly TEXTILE. The subjects thus embraced are numerous and important; of scientific importance, as involving at every step the deductions of chemistry and the principles of taste; and economically so, as elaborating from the crude and apparently worthless materials of the soil an almost infinite variety of articles of utility and elegance. Our limited space precludes the idea of a minute account, and restricts us merely to the leading features of the manufactures in question.

EARTHENWARE.

Pottery may be generally defined as the art of making vessels from clay, or from other mineral substances ground and rendered plastic like that body. The manufacture of porcelain or china is not included in this definition, inasmuch as it is semi-vitrified, and becomes translucent in the kiln. The fabrication of earthenware—that is, mere sun-dried or fire-dried vessels of clay—seems to have been one of the earliest of human arts; but pottery with a painted glaze was unknown till about the ninth century, when it was first attempted by the Arabs in Spain. Soon after, it found its way into the island of Majorca, where considerable progress was made in the art. From Majorca it was introduced into Portugal, Italy, and France, and thence into Holland. In the seventeenth century, a pottery was established at Burslem, in Staffordshire—at which, however, only the coarsest articles of brown ware were manufactured. Subsequently, the glazing of this ware by the vapour of salt—obtained by throwing handfuls amongst the heated articles in the kiln—was introduced by Mr Palmer; and in this state the manufacture continued till 1690, when two Dutchmen of the name of Elers commenced at the same place the fabrication of red unglazed porcelain, of black or Egyptian ware—the tint of which was produced by manganese—and of brown ware of a higher glaze and finish than had hitherto been produced in England. Some years afterwards, Mr Astbury was led by accident to attempt the admixture of ground flint with the finest white clay—a composition which yielded not only a finer and whiter, but a more durable ware than had previously been manufactured. It is to the late Josiah Wedgewood, however, that Britain is mainly indebted for the vast improvements which have taken place since the middle of last century in this department of her manufacturing industry. It was he who erected the first large factories in Staffordshire, and who, from his extensive chemical and mechanical knowledge, conjoined with correct taste, has made the stoneware manufactures of this country superior to those of every other.

The best clay for pottery manufacture is obtained in Dorsetshire, and another of a quality somewhat inferior is found in Devonshire. These clays are both well suited for the potter, being easily worked, standing the fire well, and becoming very white when burnt. When dug, the clay should be cleansed as much as possible with the hand, and freed from stones. At the factory, it is cut to pieces, and put into a cast-iron cylinder, about four feet high and twenty inches in diameter. An upright shaft or axis revolves in this cylinder, from which knives radiate in all directions, being so placed that the shaft with the knives attached somewhat resembles a screw. In the sides of the cylinder, knives are also fixed, which reach nearly to the shaft, and remain inactive. When the shaft moves round, the active blades cross the passive, and operate like shears in cutting the clay, which is by this process reduced to a fine pulp. The external appearance of the machine much resembles the 'pugging-mill' in fig. 7. When well ground in this manner, the clay is of the consistence of cream, and is run off through sieves of wire, lawn, and silk, so that none of the grosser parts may enter into the composition of the ware. This clay-cream, or *slip*, as it is termed, is then diluted to a standard density, and set aside in cisterns, to be used as required.

The clay thus prepared possesses remarkable plasticity; it is sensitive to the slightest pressure, and retains any form or impression given to it. But this high degree of plasticity brings with it sundry inconveniences: thus, in the firing, the articles are apt to crack, and also to become distorted. This distortion does not arise, it is supposed, merely from the evaporation of the water, but from the tendency of the particles to assume their normal condition, out of which they were forced by the processes of pressing and twisting, or 'throwing,' to which the clay is subjected. To prevent this cracking and distortion, it is necessary to add some silicious substance, incapable of contraction, to the clay. Ground flint is most commonly used for this purpose. It is prepared by cleaning the flint found imbedded in chalk, subjecting it to a red heat, and throwing it in this state into water, by which it becomes comparatively soft. It is then broken by being placed under upright shafts, which move up and down in a frame, and are called *stampers*. The broken flint is next transferred to the flint-mill, which consists of a strong wooden tub, built round a circular bottom, composed of flat pieces of hornstone. On the top of these, similar flat stones are laid, which are attached to, and driven by, strong wooden arms projecting from an upright shaft in the centre of the box. Into this tub the flint is put, and a stream of water is constantly running in, which greatly facilitates the grinding. In fig. 1, *a*, *a* represent the revolving arms, and *b*, *b* the stones fixed to them. When the flint is reduced to about the consistence of cream, it is passed through sieves, in a manner similar to the clay.

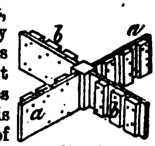


Fig. 1.

The flint and clay liquids being properly prepared, they are next mixed together in such proportions that the flint powder will be to the dry clay as one to five or six, according to the plasticity of the clay. Sometimes a little Cornish stone is also added; and the following are the proportions generally adopted in one of the principal Staffordshire factories for what is designated *cream colour*:—Silex, or ground flint, 20 parts; clay, 100 parts; and Cornish stone, 2 parts. This mixture is put into oblong stone-troughs, called *slip-kilns*, bottomed with fire-tiles, and placed above a furnace flue. Heat is then applied, and the water gradually evaporated, the liquid being constantly stirred during the operation. By this process, the mixture is formed into a fine uniform doughy mass, which is cut into pieces, and heaped together in a damp cellar, where they lie for the space

of about six months. The clay here becomes black, exhales a fetid odour, and undergoes a slight degree of fermentation, during which carbonic acid gas and sulphuretted hydrogen are disengaged. This improves both the colour and texture of the clay, and tends to bring it to a homogeneous mass. The longer the clay-paste is kept, the finer it becomes in the grain; and vessels made from it, when old, are not so apt to crack as those formed from newer paste.

The process of firing, as generally carried out, is a very wasteful one as regards the expenditure of fuel, and is attended with inconveniences. In view of these, more perfect processes have been introduced to get rid of the superfluous water: amongst others, we may notice the screw-press, and filtration by means of a vacuum. The most recent plan, and the most satisfactory in its results, is the adaptation of the hydro-extractor, or the centrifugal drying-machine, used in drying wet calicoes, &c. This consists of an outer case, in which a circular vessel with perforated sides revolves at a high velocity, a space being left between the two vessels. The clay is put into the inner vessel, which is set in motion; the centrifugal force generated has the tendency to throw the mass out of the vessel, but this being prevented by the sides, it is pressed forcibly against them, and the moisture is forced through the apertures, and falls into the space between the two cases. Such is the evaporative power of this contrivance, that a ton of clay is reduced to the necessary state of dryness by a revolution of three or five minutes.

To assist in forming the clay into a fine mass, the operation of sloping or wedging is performed at intervals during the period the clay is lying to ferment. This consists of slicing the clay with a spade, and dashing the slices together so as to expel the air which lodges in the mass. This process in large establishments is aided or performed by passing the clay through a mill. The last process previous to the throwing is the 'slapping,' which is performed by cutting masses into portions by means of a wire, provided with handles at its extremities, and dashing the pieces together again, care being taken to make them join parallel to each other; if this is not attended to, the grain being disturbed, the pieces are likely to crack during the process of baking.

The clay, being thus completely kneaded, is put upon the potter's wheel (fig. 2), where it is formed into articles of various shapes. This lathe consists of an upright iron shaft, the lower point of which turns in a socket, and the upper is fixed in a broad wooden disk. Near the top, the shaft passes through a socket attached to the framework of the lathe. In the centre is a pulley, with grooves of different circumferences, by which the speed of the shaft can be increased or lessened as circumstances require. This shaft is driven by a fly-wheel, from which an endless belt passes to the pulley. The clay is weighed

Fig. 2.

out and handed to the workman at the lathe, called the *thrower*, who dashes the mass upon the revolving wooden disk. He then dips his hands frequently into a dish of water placed beside the lathe, and pressing the clay with both hands, it gradually assumes an irregular conical form. By pressing one hand upon the top of this cone, it is again flattened down to a cake, by which operation all air-bubbles are extricated. He next lessens the speed of the shaft by shifting the belt from a small to a larger groove in the pulley, and forms the clay into the shape of the vessel required. This operation is called *throwing;* and when performed, the vessel is cut off from the disk by a wire attached at each end to a piece of wood. The vessel is then allowed to dry gradually, until it arrives at a certain point called the green state; after which it is put upon a turning-lathe, similar to that used by the worker in wood. Here it is turned to its proper shape by a sharp tool, which also smooths it, and after this, it is burnished with a steel surface.

In the green state, also, are attached handles and other appendages to vessels, this being the point at which the clay possesses its greatest tenacity, till it is burned. Handles of tea-pots, &c., are formed by squeezing the dough through different shaped orifices, which, as it issues, is cut into proper lengths, and bent into the desired forms. These being formed, are attached to the vessels by a paste called *slip*, and the seams are smoothed off with a wet sponge. The ware is next placed in an apartment heated to about 90° Fahrenheit, and fitted all round with shelving. When completely dry, they are rubbed over with hemp, and are then ready for the baking-kiln.

The articles made in the manner above described are all of a round form; but there are many which are of a different shape, and require a different process in the manufacture. Oval-shaped vessels are formed by what is called *press-work*, which is done in moulds made of plaster of Paris. One half of the pattern is made in the one side of the mould, and the other half in the other side. The parts are formed to fit each other exactly, and are joined in the same manner as the handles are to vessels. Imitations of flowers and foliage, and all delicate pieces of ornamental ware, are *cast* in moulds of plaster of Paris. The clay is poured into the mould in a thin state, and is there left for a certain time.

The plaster absorbs the water of that portion which lies nearest to it, and solidifies the mixture of clay and flint; the central fluid portion is then poured out, and the film or coating of clay left to dry. Another portion of fluid-clay and flint is then poured in, which is passed through the same process as before. The mould is placed in a stove, and after being dried, is touched up and rendered perfect in outline by a modeller.

Plates, saucers, wash-bowls, &c., are made by the process called 'flat-ware pressing.' A mould, *bb*, fig. 3, is made, which gives the outline of the internal shape of the article; and a profile-plate, *cc*, that of the outside. The latter is mounted upon a frame or carrier, by which the depth can be adjusted so as to give any desired thickness to the material. The mould, *bb*,

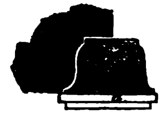


Fig. 3.

is placed upon a whirling-table, *aa*, and the clay is pressed down upon its surface, and moulded by the hands till it assumes the proper shape. Where an exact outline is required, the profile-mould is used. The thickness of the material is represented by the white space between the outlines *b* and *cc*, fig. 4.

When the ware is ready for the kiln, the articles are placed in baked fire-clay vessels called *sags* or *saggers*. These vessels are made of inferior clay, by the workmen during the intervals of their work, and are from six to eight inches deep, and from twelve to eighteen in diameter. The sags are packed full of the dry ware, and are then piled above each other in the kiln, the bottom of one sag forming the cover of another. These rude dishes are necessary, to prevent the ware from being suddenly and unequally heated, and also to protect it from the smoke and dust of the kiln.

Fig. 4.

Fig. 4 represents one method of packing articles in the sags. *aa* is a section of a sag, provided with projections on which the article, *bb*, is suspended. In the inside of this, a second article may be placed, as the jug shewn by the dotted lines. A second sag, as *dd*, is placed above the first, the bottom forming the cover or top to *aa*. In packing flat articles, as plates, little pieces of clay, of various shapes, as shewn at *a*, *b*, *c*, fig. 5, and known as cock-spurs, stilts, &c., are placed between the articles, as shewn at *d*, fig. 5; this keeps each article separate.

Fig. 5.

The body of a pottery-kiln is generally of a conical shape, covering and protecting from the weather the fire-kiln, which is circular, and provided with a domed top, as *aa*, fig. 6. The furnaces, six or eight in number, are placed equidistantly round the kiln, as *b*, *b*. The smoke escapes through the apertures made in the dome. The door for obtaining access to the interior is shewn at *c*. When the kiln is filled with the sags, it is built up, and fire applied to the furnaces. The heat is increased gradually, from the time the fire is put on, till the ware is found to be properly burnt. To ascertain this, the workman draws from the kiln what is called a *watch*, and if this is found to resemble in colour a previously burned vessel, he allows the kiln to burn a little longer, and then opens the doors of the furnaces carefully, so as to lower the heat by slow degrees. The burning, or *baking*, as it is called, usually lasts from forty to forty-two hours, after which the kiln is allowed to cool very slowly. When the ware is taken out of the sags, a child makes the pieces ring with the handle of a brush, used for dusting them, and then immerses them in the glazing material. The glaze is kept in a large tub, into which the articles are put by the child, and lifted out by a man, who shakes them in the air, and places them on a board, to be conveyed to the glazing-kiln.

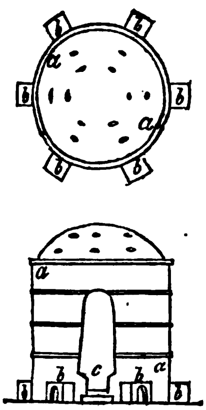


Fig. 6.

'Three kinds of glazes,' according to Dr Ure, 'are used in Staffordshire—one for the common pipe-clay or cream-coloured ware; another for the finer pipe-clay ware, to receive impressions, called *printing body;* a third for the ware which is to be ornamented by painting with the pencil. The glaze of the first, or common ware, is composed of 53 parts of white-lead, 16 of Cornish stone, 36 of ground flints, and 4 of flint-glass: of the second, 26 parts of white felspar, fretted with 6 parts of soda, 2 of nitre, and 1 of borax; to 20 pounds of this fret, 26 parts of felspar, 20 of white-lead, 6 of ground flints, 4 of chalk, 1 of the oxide of tin, and a small quantity of the oxide of cobalt, to take off the brown cast, and give a faint azure tint, are added. As to the ware which is to be painted, it is covered with a glaze composed of 13 parts of the printing colour fret, to which are added 50 parts of red-lead or litharge, 40 of white-lead, and 12 of flint; the whole having been ground together.'

The above compositions make a very clear, hard glaze, which is not affected by vegetable acids, and preserves its lustre for an indefinite time. When covered with the glaze, the vessels are put into sags, which have been previously glazed with a composition of 13 parts common salt and 30 parts potash. They are then put into the glazing-kiln, which is usually smaller than the biscuit-kiln, the sags being piled in the same manner as at the first burning. The heat of the glazing-kiln is very low at first, but gradually increases until it reaches the melting-point, when great care is necessary to prevent the temperature from suddenly falling. To ascertain when the temperature is high enough, balls of red clay, coated with fusible lead-enamel, are employed. When these balls become of a slightly dark-red colour, the temperature is sufficient to glaze ordinary pipe-clay ware. The fire is kept on for about fourteen hours, after which very little fuel is added, and the kiln is gradually allowed to cool. The vessels are again tried by being slightly struck by a small wooden hammer, when, if they ring freely, they are sound.

The colouring of pottery is performed either by what may be called painting, or by printing. The colours used in producing the *dipt* or *sponged* ware are of a very cheap kind, as it is only for common purposes that this material is employed. In dipt ware, the colours are dropped on before the ware is burned; and in sponged ware, when it is in the biscuit state. A black dip is made from manganese, ironstone, and clay-slip; a drab, by nickel and slip; a blue, by cobalt and slip; a yellow, by yellow clay alone, or by a compound of red and white clay; and a red, by a natural red or brown clay, which will burn red.

The colours used for painting and printing on ware are similar to one another, excepting that the colours for printing are more expensive; both, however, form an important and extensive part of the materials of a pottery. The manufacturers of earthenware are much occupied with the improvement of the variety and beauty of the colours, as well as of the patterns or styles that are produced, and hence a great emulation exists among those employed in the trade. The blue colour in *printing* is produced from cobalt, which is used with flint, ground glass, pearl-ash, white-lead, barytes, china-clay, and oxide of tin in reducing its strength; the brown, by ochre, manganese, and cobalt; the black, by chromate of iron, nickel, ironstone, and cobalt; the green, by chrome, oxide of copper, lead, flint, and ground glass; and the pink, by chrome, oxide of tin, whiting, flint, ground glass, and china-clay, which are mixed in various proportions, fused together at a high temperature, then pounded and mixed with oil. The colouring matter is ground upon a porphyry slab, with a varnish prepared from a pint of linseed oil boiled very thick, four ounces of rosin, half a pound of tar, and half a pint of the oil of amber. This transfer varnish is very tenacious, and requires to be liquefied by heat before being used.

The figure or design to be fixed upon the vessel is engraved in the usual way upon copper-plate, which is rubbed over with the colouring matter prepared as above, and the impression is taken upon a thin unsized paper made for the purpose. The printed paper is placed upon the vessel, and is rubbed with a roll of flannel about an inch and a half in diameter. After this the vessel is set aside for a little, to allow the figure to become fixed, when it is dipped in water, and the paper washed off with a sponge. The impression being transferred, the vessel is dipped in alkali to destroy the oil, and then immersed in the glazing matter. Printing above the glaze is performed by covering the copper-plate with the colouring matter as before, and brushing off what is superfluous. A cake of glue, stiff enough to be handled, is then laid upon the plate, which receives the impression of the figure. The glue cake must be very cautiously lifted off from the plate, and transferred to the surface of the glazed ware which it is intended to print. The same cake will answer for transferring a number of impressions, by simply washing its surface.

The ornaments on common stoneware vessels are made in relief in France, and hollow in England, by means of a mould in relief which is made to pass over the article.

These hollows are filled with a clay paste of the colour required, while the vessel is turning upon a lathe. Net-work and variegated decorations are made in this manner by passing different layers of coloured clay over each other.

In the finer pieces of ornamental ware, as porcelain casts, delicate net-work often covers part of the surface; this is put on by dipping actual lace in the slip, and passing it round the articles in a thoroughly saturated condition. The heat of the furnace destroys the thread, but leaves the clay thoroughly burnt. Messrs Boote, of Burslem, have patented, and introduced into successful practice, a process remarkable for the grace and beauty of some of its productions. It consists in inlaying one clay upon another—blue upon white, or white upon blue, for instance; certain effects and combinations of colour are thus easily effected, which before were impossible to be produced.

Metallic lustres, from gold, platina, copper, iron, &c., are produced by dissolving any of these metals in aqua regia, and applying it to the vessels. Over the metallic solution, a glaze composed of 60 parts of litharge, 36 of felspar, and 15 of flint, is put, and the vessels burned as before. These *lustres*, as the wares so coated are called, have a rich metallic appearance, and would be highly prized if they were not so cheap and common.

STONEWARE.

This is a ware intermediate between common earthen-ware and porcelain, and may be described as a coarse kind of porcelain, made from sandy clay, containing oxide of iron and a little lime, to which it owes its fusibility. The glazing is performed by throwing common salt into the heated furnace; this is volatilised and decomposed by the joint agency of the silica of the ware and of the vapour of water always present; hydro-chloric acid and soda are produced—the latter forming a silicate which fuses over the surface of the ware, and gives a thin but excellent glaze. The salt is not thrown in until the kiln has been raised to its greatest necessary temperature. Ware of this kind, we have said, is generally made of sandy clay and a little sand, to keep the body open, or less compact; but for large vessels, pot-sherd (which is ware that has been fired, and then ground) is employed, to render the body still more open and porous, and also to give it a capability of withstanding sudden heats or colds. This ware is much used for chemical purposes; it is exposed to the action of the flame during burning, whereas other kinds of ware are protected by saggers.

Stoneware of the Wedgewood colour is a semi-vitrified ware, which is not susceptible of a superficial glaze. It is composed either of barytic earths, which act as a flux upon the clay, and form an enamel, or by the clay being rubbed over with a compound vitrifying paste. Semi-vitrified ware undergoes an operation called *smearing*, by which the vessels do not require to be immersed in glaze. They are merely put into the glazed sags, which communicate by reverberation a lustre nearly equal in brilliancy to glaze itself. Messrs Green, of Lambeth, have produced, in stoneware, possibly the largest vessels yet manufactured; these are designed for breweries and distilleries, and are sometimes of enormous dimensions.

PORCELAIN.

Porcelain or china is a fine-grained, compact, very hard, faintly translucent ware, of which there are two kinds—one called hard, and the other tender or soft. *Hard* porcelain is composed of a clay containing silica, which is infusible, and preserves its whiteness in a strong heat, and of a flux consisting of silica and lime. The glaze of this ware is earthy, and admits of no metallic substance or alkali. *Tender* or soft porcelain consists of 'kaolin, Cornish stone, and bones.' It is glazed with artificial glass, into the composition of which silica, alkalies, and lead enter.

Kaolin-clay is the largest ingredient in porcelain ware. It is composed of alumina and silica, and is obtained in large quantities in China, Germany, France, and in the county of Cornwall in England. Kaolin is very friable in the hand, and is with difficulty formed into a paste or dough which will bear to be worked. That found in Cornwall is whiter than the foreign clays, and more unctuous to the touch. It is a decomposed felspar—one of the constituent minerals of granite—which has accumulated in vast quantities in certain localities, having been no doubt washed down by rains from the weathered and exposed surface of granitic rocks. When the kaolin or china clay of Cornwall is mixed with alluvial matter, it is broken into lumps, and thrown into a running stream; this carries off the firm particles into catchpools, where the sediment is allowed to settle, and the water is drawn off, leaving the clay.

As the processes which the material goes through in its manufacture into the various forms of porcelain ware, very closely resemble those which we have already described in our remarks on pottery or earthenware, it is unnecessary here to repeat them.

Among recent inventions in the manufacture of porcelain, may be mentioned Parian or statuary porcelain, the beauty of which will doubtless be familiar to most of our readers through the medium of the reproductions of modern sculpture, on a reduced scale, by the celebrated firm of Minton & Co., and Messrs Copeland. The use of a soft felspar instead of the Cornish stone, is that which chiefly imparts the peculiar effect. Great care is necessary in producing articles of this material: they are generally cast in moulds, in a number of pieces; and as the process of firing contracts the size to the extent of one-fourth, great skill on the part of the artist is called for. Unglazed porcelain has the appearance of marble or alabaster, and is much used for ornamental articles and statuettes. It is known by the name of 'biscuit.' In the adaptation of this material, the Sèvres manufactory in France has been long distinguished. The English manufacturers are, however, fast following them, if not already equal. Messrs Minton have succeeded in introducing specimens of this manufacture, which, for their 'freshness of effect and excellent taste,' have attracted great attention. Parian porcelain far exceeds in beauty and softness the ordinary porcelain biscuit; the effect arises from the light penetrating to a certain depth, while in biscuit the light is reflected at the surface, giving it a 'cold appearance.'

A variety of hard porcelain has been introduced by Messrs Minton for the dishes, &c., used for chemical purposes, and with such success, that the monopoly enjoyed by the continental firms is likely to be, if it has not already been, broken through.

In painting on porcelain, the same colouring materials are used as those employed in colouring glass or earthen-ware. In all the more delicate patterns, they are laid on with a camel-hair pencil, and generally previously mixed with a little oil of turpentine. Where several colours are used, they often require various temperatures for their perfection; in which case those that bear the highest heat are first applied, and subsequently these that are brought out at lower temperatures. This art of painting on porcelain, or *in enamel*, is of the most delicate description: much experience and skill are required in it, and with every care, there are frequent failures; hence it is attended with considerable expense. The gilding of porcelain is generally performed by applying finely divided gold mixed with gum-water and borax; on the application of heat, the gum burns off, and the borax, vitrifying on the surface, causes the gold to adhere: it is afterwards burnished with bloodstone, agate, or other polishers.

Porcelain vessels are very brittle, and are easily damaged, which accounts in some degree for the high price at which they are sold. It is calculated that, after being manufactured, one-third of the articles are found

damaged, most of which takes place in the kiln. English and foreign porcelains differ considerably in their composition, which accounts for their difference of transparency, brittleness, and fitness for chemical purposes.

'There are some considerable manufactories of pottery-ware in the north of England, and one or two in Yorkshire; but the principal site of both porcelain and pottery wares is in the modern borough of Stoke-upon-Trent, which contains a population of about 70,000 persons engaged directly or indirectly in these manufactures.' The principal seats of porcelain manufacture in continental Europe are Sevrès near Paris, Tournay in Flanders, Dresden, Berlin, and Florence; the wares of Sevrès being as yet unequalled in their translucency, glaze, and gilding, and in the elegance and taste displayed in their shape and figure-paintings.

BRICKS—TILES—DRAIN-TUBES.

Bricks formed of tempered clay, and artificially hardened by heat, may be termed a species of artificial stone. They have been used for building purposes from a very early period in the world's history. Anciently, bricks were of two kinds—sun-dried and fire-burnt. The former were much used in the buildings of Egypt and Babylon—they are still used in the East. The humid climate of England, however, requires a more careful and certain hardening than that which the sun gives; hence the use of fire for this purpose. It was not till after the Norman Conquest that bricks were much used in this country. It was, however, in the reign of Henry VIII. that brick as a building material attained a high repute. Its use was mostly confined to the erection of large buildings, and in these a great amount of decorative effect was often produced. Mr Dobson, in his excellent treatise on *Bricks and Tiles* (London: Weale), refers particularly to the decorative details of the manor-house at East Barsham, and of the parsonage-house at Great Snoring as worthy of notice. He also gives an illustration of ornamental brick-work as exemplified in a house, No. 43 St Martin's Lane, London. Up to the period of the Great Fire in London, the dwelling-houses were chiefly composed of wood; after that event, the danger arising from this cause was obviated in some measure by the compulsory use of bricks, not only for the walls, but for the ornamental parts of the house. From this cause may be traced the erection of many fine specimens of brick-work throughout the metropolis. The minute tracery-work which abounds in many specimens, appears to have been executed by tools after the erection of the walls.

It is in England that the manufacture of bricks is of such importance; in Scotland, it is less practised, owing to the ease with which stone well adapted for building is obtained.

Up to the close of the last century, bricks were untrammelled by the Excise; by the 24 Geo. III. c. 24, a duty of 2s. 6d. per thousand was imposed on bricks of all kinds. By the act 34 Geo. III. c. 15, this was raised to 4s. The uniformity, however, of the imposition was done away with by the division of bricks into 'common' and 'dressed,' different rates of duty being laid upon each kind. By the same act, tiles were taxed. By the act 3 William IV. c. 11, 1833, the duties on tiles were repealed; and in 1835, the duty on common bricks was raised from 5s. to 5s. 10d. per thousand. The distinction in bricks as to size and quality was in 1839 done away with by the act 2 and 3 Victoria, c. 24, by which 5s. 10d. per thousand of duty was charged, the only condition imposed being, that each brick was not to exceed 150 cubic inches. The size of an ordinary building-brick was nine inches long, four and a half broad, and three thick. This new act gave a great impetus to the manufacture, as by it many restrictions as to the shape were removed, and ornamental bricks, &c., allowed to be made. Still, however, the 'building interests' felt the Excise restrictions upon the article to be exceedingly harassing in their operation, and depressing in their influence upon the progressive improvements which would otherwise have been introduced into the manufacture. In consequence of their repeated representations, and the advocacy of the journals devoted to their interests, the duty on bricks was wholly repealed by a recent act, and the trade left free.

The increase in the quantity of bricks annually manufactured has been very marked during the last half-century. In 1821, the number in England and Scotland amounted to nearly a thousand millions; in ten years it had increased to twelve hundred millions; and in other ten years, to nearly eighteen hundred millions. The rapid increase of railways has had a great influence in extending the trade: Mr Dobson calculates the quantity required for each railway bridge at 300,000; and for a mile of tunnelling, at fourteen millions.

The common superficial clay, which is so liberally spread over our island, must be familiar to every one. It is of various colours—yellow, red, or bluish, according to the amount of iron oxide which it contains—is more or less mixed up with sand and fragments of rock, and when softened, becomes plastic and tenacious. What is chiefly necessary is a due admixture of alumina and silica—that is, clay and sand; for though pure clay may be made into extremely hard bricks, they are apt to shrink and crack in the burning; while too much sand renders them brittle and friable. As to the presence of a little lime, magnesia, or oxide of iron, it is rather liked than otherwise, these materials giving agreeable colours to the finished article. For bricks, slabs, crucibles, &c., which have to resist the action of fire, some of the coal-measure or stratified clays are generally had recourse to; these, from their greater purity, and a certain percentage of silica, being susceptible of a more thorough baking. In England, the Windsor, Stourbridge, and Welsh fire-clays are esteemed the best—the latter yielding those large square slabs employed in the construction of drying-kilns, brewers' coppers, sugar-boilers, smelting-furnaces, and the like.

From the process of brick-making varying in different localities, our space compels us to give merely a general notion of the manufacture. Bricks are of different qualities. Thus, the *malms* of the London bricklayer are of a yellowish uniform colour and texture, prepared by an admixture of ground chalk; *seconds* are those less uniform in colour and texture; *cutters* are those made so soft, as to be cut into form for arches of windows; *fire*-bricks are prepared to withstand the heat of fires and furnaces, and of such there are varieties known as *Welsh lumps*, *Windsors*, &c.; *paving*-bricks, made for the purpose their name implies; *compass*-bricks, of a circular shape, for lining walls and chimneys; *Dutch clinkers*, at one time imported from Holland, but now made in England, a compact variety often used in stables, about six inches long, three broad, and only one in thickness. The *floating* bricks known to the ancients, and recently revived by M. Fabroni, are composed of a silicious or infusorial earth, commonly known as fossil or mountain meal.

After having decided on the locality of the brick-field, the first process is the removal of the earth-covering. The clay or brick-earth is then dug up, and placed in heaps, and turned over, to expose the masses to the mellowing action of the winter air and frost. The next process is tempering the clay, that is, preparing it in the form of a homogeneous paste for the moulder. This is still effected in many districts by hand, turning it over and over, and treading it with horses or men. In the improved processes, tempering is effected by the use of revolving rollers, between which the clay is passed; or by what is termed a pug-mill. This consists of an upright conical tub, the small end downwards; in which a shaft, fitted with projecting knives or cutters, is made to revolve by horse-power. The knives knead and cut the clay, and force it through the bottom of the mill,

where it is cut into lumps, and laid aside till required. Fig. 7 shews an improved form of pug-mill, known as

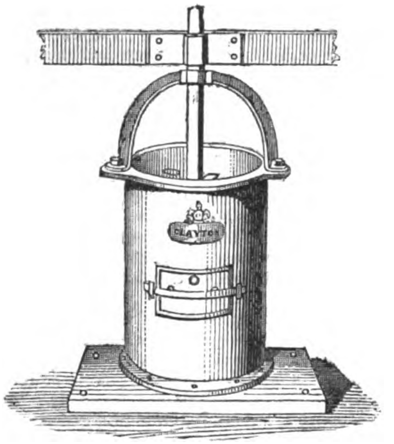


Fig. 7.

Clayton's Archimedean knife pug-mill. Great care is taken at the outset to free the clay from all stones, pebbles, &c.; the presence of one of which, even of small dimensions, will cause the brick to crack in drying. Where much gravel is mixed with it, which no amount of hand-picking could remove, it is washed, and reduced to the consistence of a fluid; in this state, it is passed through a grating, which retains all the gravel, and allows the fluid clay to pass.

Where limestone abounds in clay, it is ground between rollers, which crush the limestone; of which a small piece, if left, will cause the brick to have air-holes made in it while burning, from the carbonic acid gas evolved by the heat.

Where marl is used for malm bricks, it is ground to a pulp in the wash-mill, and mixed with lime in the shape of a thick liquid. The whole is then placed together, and allowed to become firm enough to bear walking on its surface; it is then covered with fine ashes, and allowed to stand all the winter till spring, when the whole are well mixed together.

The next process is the moulding. The mould consists of a frame the size of the brick, without top or bottom, as *aa*, fig. 8. In the improved form of solid bricks, indentations, as *c*, are made in the upper and under faces of the brick (*b*, fig. 8). These form a 'key' to the mortar, securing efficient bond. To form this indentation, projections are made in the bottom of the mould and in the top. The moulder works at a bench; and his art consists in dashing in a lump of the tempered clay so as completely to fill up the mould, the superfluous clay being dexterously taken off with what is called the *strike*. To prevent the clay adhering to the mould, it is either dipped in water, or sprinkled with sand: if the latter, it is termed 'pallet-moulding;' if the former, 'slop-moulding.' In slop-moulding, two moulds are required, as the mould with its newly made brick is carried off by the attendant boy to the drying-ground, where the brick is deposited, the moulder the while forming another brick in a second mould, which is finished by the time the boy returns with the first.

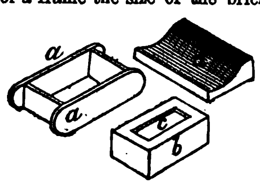


Fig. 8.

In pallet-moulding, one mould alone is used, the bricks being turned out on a pallet when made, and taken by the boy in a hack-barrow to the drying-floor. By slop-moulding, a man can make 10,000 per week; while by pallet-moulding, he can make as many as 36,000; in the latter case, however, the moulder has an assistant.

The next process, or that of drying, is one which requires considerable attention. 'The great point,' says Mr Dobson, 'to be aimed at is to protect them against sun, wind, rain, and frost, and to allow each brick to dry uniformly from the face to the heart.' The drying is sometimes effected under cover; but more frequently the 'hacks' are built in the open air, and covered with various substances, as straw, tarpaulin, &c.

The last process is the burning, which is performed either in *kilns* or in *clamps*—the latter being large square piles of bricks skilfully built up, with layers of fuel between, called *breeze*, and also with flues filled with coal, cinders, and wood, to facilitate still more the process of combustion. Baking in kilns, however, is preferable, as there is not only less waste, and less fuel consumed, but the bricks are sooner ready for the market. 'The kiln,' says Dr Ure, 'is usually 13 feet long by 10½ feet wide, and about 12 feet in height. The walls are one foot two inches thick, carried up a little out of the perpendicular, inclining towards each other at the top. The bricks are placed on flat arches, having holes left in them resembling lattice-work; the kiln is then covered with pieces of tiles and bricks, and some wood put in to dry them with a gentle fire. This continues two or three days before they are ready for burning, which is known by the smoke turning from a darkish colour to transparent. The mouth or mouths of the kiln are now dammed up with pieces of bricks piled one upon another, and closed with wet brick-earth, leaving above it just room sufficient to receive a fagot. The fagots are made of furze, heath, brake, fern, &c., and the kiln is supplied with these until its arches look white, and the fire appears at the top; upon which the fire is slackened for an hour, and the kiln allowed gradually to cool. This heating and cooling are repeated until the bricks are thoroughly burned, which is generally done in forty-eight hours. One of these kilns will hold about 20,000 bricks.'

Clamp-dried bricks require to be thoroughly dried previous to burning. Where kilns are used, the heat can be regulated so nicely that comparatively damp bricks may be put in, which are first dried by a gentle heat. In the clamp, as the heat is got up almost immediately, it would cause damp bricks to fly in pieces.

Tiles are prepared much in the same way as bricks; only, from their being thinner, and of a more intricate form, they require to be made of finer and tougher materials, and are always burned in kilns. They are of different kinds, according to the use to which they are applied—as *plain* and *pan* tiles, *ridge* tiles, &c. In fig. 8, *d* shews the form of the mould for a 'pan-tile.'

Machines are sometimes used for the purpose of

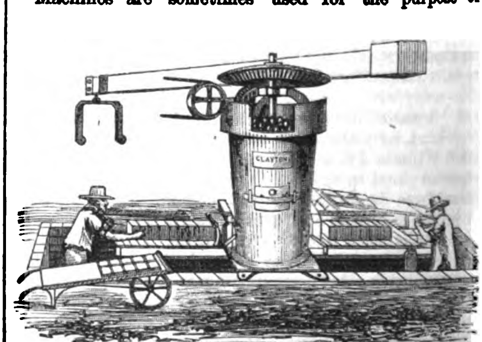


Fig. 9.

moulding the bricks. They are, however, chiefly available in cases where a large number of bricks are to

be made. For small brick-works they are far from being economical, the cost of moulding being a very small proportion to the other items of brick-making. The best known machines are those of Clayton; a solid brick-making machine of this maker is shewn in fig. 9. Mr Prosser of Birmingham has introduced a patent brick-making machine. The clay is used in a state of dry powder. This being put into metal moulds, and subjected to an enormous pressure, the particles cohere with great force, and can be immediately carried to the kiln.

Drain tiles and tubes are always made by machine: the former are of a horseshoe shape, and are made by rolling out the clay into sheets between two cylinders, and thereafter cutting out the necessary oblong parts, and bending them into the proper shape by an ingenious assemblage of endless chains, levers, pulleys, &c. The tubes are made by pressing clay from a cylinder through dies of the size and shape of the tube wanted, the cutting off of the lengths being also effected by the machine. Hollow bricks, now so much used, are also made by machinery. In fig. 10 we give diagrams of the dies used for forming various hollow articles: *a* is the die for the hollow brick shewn in perspective at *e*; *b*, a die for a circular drain-tube; *c*, a die for a drain-tube with flat bottom; and *d*, a die for a recently introduced form of hollow earthenware step for fire-proof staircases. In all these, the clay is forced through the spaces represented white; the shaded parts being the iron portion of the dies. An immense variety of machines have been introduced for this branch of the earthenware manufacture.

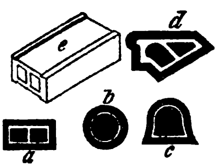


Fig. 10.

For architectural decorations, figures, vases, &c., on a large scale, a variety of argillaceous compounds are now in use, the principal of which is known by the name of *terra cotta*—literally, baked clay. This composition consists of pipe or potters' clay, a fine colourless sand from Ryegate, and pulverised potsherds. These are worked into a homogeneous paste, which is modelled or cast into the figure required, then slowly dried in the air, and ultimately fired to a strong hardness in a proper kiln. Tobacco-pipes are made of a finely ground white plastic clay (to which they have given the name), chiefly found in the Isle of Purbeck in Dorsetshire. This clay being worked into paste and dough, in the same manner as the finer sorts of potters' stuff, is next rolled into cylinders for the stems, and into balls for the bowls. These are then pressed to the desired form in metallic moulds, and pierced with a wire; dried for a day or two; scraped, polished, and dipped; and ultimately fired in a baking-kiln for ten or twelve hours. A clever workman, aided by a boy, can easily make from five to six gross of plain pipes per day.—For *Meerschaum*, see MINING—MINERALS.

ENCAUSTIC TILES—TESSERÆ—MOSAICS.

The term *mosaic* is said to be derived from the Greek word *mousaikon*, elegant or polished; and is now applied to the art of imbedding or inlaying in a cement fragments of different coloured substances, so as to produce the effect of a picture. This art was practised at a very early period, and was introduced into Italy by the Byzantine Greeks. Magnificent specimens are to be seen in St Peter's at Rome, and in the chapel of St Lawrence at Florence, where precious marbles, agates, jaspers, avanturines, malachites, &c., constitute the coloured tesseræ.

The ancients applied mosaics chiefly to pavements, for which they are admirably adapted. Specimens of highly decorated pavements are also frequently met with in the grand ecclesiastical structures of the middle ages. Such is the beauty, as well as the durability, of this species of pavement, that attempts have frequently been made in this country to revive the art; and recently Mr Minton has succeeded in carrying out the patent process of Mr Wright for a new style of mosaic. Some of the most elaborate subjects, as coats of arms, are so finely executed, that it is difficult, at a cursory glance, to get rid of the idea that they are the fine products of the pencil. Great care is taken in the preparation of the clay, it being repeatedly washed and purified, and passed through fine sieves. The pattern is first carefully modelled in clay, the parts constituting the device being depressed about a quarter of an inch, and from this a cast is taken in plaster, and placed in a metal frame. To make a tile six inches square, one $6\frac{5}{8}$ inches is made, in order to allow for contraction. A sheet of fine clay is pressed upon the plaster-cast, and a sunk impression is thus obtained. The thickness of the tile is made up by coarser clay, after which it is placed in the press, and the proper degree of solidity given to it. When the pattern is of different colours, the following process is followed. The clays of different colour are poured into the indented parts of the pattern, covering the whole surface of the tile, and are allowed to dry. The surface is then scraped, so as to expose the pattern, and the tile is placed in the drying-house for a fortnight or three weeks, and finally subjected to an intense heat for sixty hours, which brings out the colours with great brilliancy.

A species of ornamental tile is now made after the manner of the Alhambra. In forming the tiles, the clay is pressed in embossed moulds, which give the various grooves and indentations. They are then fired; and after this process, the hollow parts are filled up with enamels of various colours, which, after firing, produce a very brilliant effect. The pattern being in low relief—a distinguishing characteristic of the Alhambra style of ornamentation—the tiles are capable of being used either for floors or the covering of walls. A beautiful exemplification of this style may be seen in the Alhambra Court at the Crystal Palace of Sydenham.

One way of forming slabs for mosaic pavement is this: Plain self-coloured tiles, or tesseræ, are made of powdered clay, subjected to great pressure in strong steel dies, which gives uniformity of size and shape. They are then formed into slabs of any size required, by placing them, when being fired, on a smooth platform, with the face downwards, the arrangement being such as to produce the pattern intended. In this position, liquid cement is poured upon them, which unites them together.

There is a new style of mosaic pavement, manufactured by Alfred Singer & Co., composed of tesseræ of vitreous clays. The clay, after due preparation, and colouring with metallic oxides, is formed by the machine into long thin ribbons about $\frac{3}{8}$ inch thick, and three or four feet long; out of these the various patterns or shapes of tiles required are cut by machinery, so as to obviate the necessity of chipping to make them fit. A number of these are laid with their face downwards, to form the pattern or design, and the whole united to form a slab by pouring liquid cement over the baked surface.

Roman Mosaics.—The fabrication of these pretty ornaments is altogether a different art. The following is an account of the peculiarities of the manufacture, as given by M. Pistrucci, the chairman of the jury of the Great Exhibition on ceramic manufactures:—The mosaics which are made in these times are composed of pieces of glass, sometimes called *smalt*, and sometimes paste. They are made of all kinds of colour, and every different hue; and for large pictures they take the form of small cakes. For small works, they are produced in threads, varying in thickness from that of a piece of string to the finest cotton thread. Heaps of these, of all tints and colours, are prepared; a plate or slab of copper,

marble, or slate, is then provided, of the size and thickness required for the intended work. This slab is hollowed out so as to resemble the bottom of a box or a tray, to a depth proportioned to the work; this may vary from an inch to the eighth, or even the sixteenth of an inch, if the work is to be small. This hollow is then filled with plaster of Paris, well smoothed, on which the outline of the proposed design is very accurately traced, and an inked pen is passed over the outline, to preserve it. Very few tools are required by the workman; but for the large works, where comparatively large pieces are to be inserted, small sharp-cutting hammers are made use of for splitting the cakes and reducing them to their proper size and form. Pincers, also, of different forms are used, for placing them equally. In very small works, instead of hammers, sharp-pointed pincers are made use of, like those with which diamonds are taken up, and sometimes a small tool like a scarpello. The heat of an oil-lamp is required to enable the workman to draw out the strips of glass to the fineness he wants, even to that of a hair. When all this is ready, the first operation is to dig or scoop out, with a scarpello of the proper size, a small piece of plaster of Paris from the bottom of the box or tray, without injuring the outline; this is filled up with a kind of mastic, like that which is used to fix panes of glass in the sashes or frames of a window, and the required piece of smalt or glass is then pressed into the mastic or composition. In this way, step by step, and from day to day, repeating the operation of scooping out a small piece of plaster of Paris, and never losing sight of the outlines, they gradually fill up the whole tray. In works of considerable dimensions, the workmen place the tray or plate before them, as painters place the canvas on which they are painting, and have the original always close to them. For smaller works they sit at a table, as if writing, and generally keep their work flat on the table. . . . . When this operation is completed, it is passed over a stone made perfectly smooth, and cleaned of every kind of dirt. But as it will always happen that interstices, however minute, will be left more or less between the several small pieces of smalt inserted in the mastic, these are to be carefully filled up with heated wax, applied with hot iron implements from a pallet on which it has been prepared for the purpose; and much of the good effect and finish of the work will depend on the ability and care of the workman by whom this operation is performed.' The workman—named the *mosaiciste*—does not produce the design, or even trace it on the plastic; this is the work of a separate class, the designers. The manufacture of Roman mosaic has, we understand, been always confined to Rome, no other town or country competing with it. Of late, however, imitations have been produced in this country.

GLASS.

The origin of the glass-manufacture is involved in the greatest obscurity, and has given rise to much ingenious speculation, upon which little or no dependence can be placed. Glass beads have been found on the bodies of Egyptian mummies which are known to have been embalmed 3000 years ago. Pliny says that the art of glass-making was accidentally discovered by some shipwrecked Phœnician mariners, whose vessel was laden with fossil alkali, a component part of glass. On kindling a fire on the sand to prepare some food, and placing their cooking-vessels on pieces of the substance just named, the sand, by the agency of the fire and its union with the alkali, became vitrified; hence, according to this authority, the discovery of the art.

The first glass-manufactory of any note was established at the village of Murano, near Venice. The glass produced here was superior to any in Europe, and for a long time the principal supply was obtained at this place. The Venetians were long celebrated for making mirrors, which they brought to considerable perfection. Window-glass appears to have been made in England in the middle of the fifteenth century, but it was of an inferior description. In 1557, the finer sort of window-glass was manufactured at Crutched Friars in London. The first flint-glass was made at Savoy House in the Strand; and the first plate-glass for mirrors, coach-windows, and the like, was fabricated at Lambeth in 1673, by Venetian workmen, brought over by the Duke of Buckingham.

A glass-house is usually built in the form of a cone, from 60 to 100 feet high, and from 40 to 80 feet in diameter at the base. The furnace is placed in the centre of the building, and is generally of an oblong figure, although sometimes circular. Below the furnace is an arched gallery, extending right across the building, and terminating in folding-doors, large enough to admit a barrow for carrying out the ashes. In the sides of the furnace are apertures called working-holes, through which the materials are put into the pots, and the blowing-tubes inserted. In a crown-glass manufactory, the furnace generally contains from four to six pots; but this will altogether depend upon the size of the building. The stone used in constructing glass-furnaces must be of the finest quality; that called fire-stone, got from Coxgreen, in the neighbourhood of Newcastle, is considered the best for this purpose.

Crown-glass.

Crown or window glass is usually composed of alkalies, and fine white sand. The best sand for glass-making is that which contains most transparent particles, and this is found in large quantities in that brought from Lynn Regis in Norfolk, and the western coast of the Isle of Wight.

Up to a period dating thirty years ago, kelp, obtained by the burning of a certain sea-weed, was the alkali used in glass-making. But in 1792, Le Blanc discovered a method of converting common salt into carbonate of soda; thus affording to manufacturers a readily obtained and inexhaustible supply of alkali. From the introduction of this, a new epoch in the history of glass-making may be dated.

The base of all glass is that above stated, but to the alkali and the silica (sand), lime and other ingredients are applied. The lime, in due quantity, promotes the fusion, and improves the quality of the mass; but if too much is present, it renders the glass difficult to work, and subject to devitrification. Alumina, which is also sometimes added, and which is always accidentally present, renders the glass liable to devitrification. Iron, too, is present, and as this colours the glass, its effects are got rid of by the addition of manganese. When the soda is introduced in the form of sulphate, or Glauber Salt, charcoal is introduced, to decompose the salt. Arsenic is also added to decompose other ingredients. The proportion in which these various materials—as sand, soda, charcoal, chalk, manganese, and iron—are mixed, varies with circumstances, and according to the fancy of the manufacturer. To this mixture of materials, a portion of broken waste-glass, termed *cullet*, is added, to promote the fusion.

The pots in which these materials are placed, to be subjected to the action of the furnace, are all made by manual labour, being built up bit by bit, and occupy many months before being ready for use. They are made of the best Stourbridge clay, mixed with about one-fifth of ground potsherds, are carefully dried for months, and thereafter exposed to the action of the kiln. Their average duration is five to seven weeks. Flint and compound glasses are melted in *covered* pots, to protect the mass from the action of the flame and smoke which would bring about a chemical action, tending to precipitate in a solid state the lead and other metals used. The furnace in which the pots are deposited is circular in form, the fire-bars in which the fuel is consumed being in the centre, and nearly on a level with the floor of the glass-house. A series of subterranean

passages are placed at various angles with the main or transverse passage, which serves as the ash-pit, a supply of air being thus obtained from different directions. The pots are placed round the circumference, at regular intervals; one on each side of a flue. An aperture is left in the brickwork, in the space between two flues, through which the materials are passed to the pots. The heat is regulated to any degree of intensity, by opening or shutting apertures admitting more or less air to the grate bars.

The materials are introduced into the pots by means of an iron shovel, the pots being previously brought to a white heat. The aperture is then closed with a stopper, and carefully luted with clay. After subjection for some time to a high temperature, the whole become thoroughly fused, and enter into chemical combination; the silica uniting with the bases, soda, lime, &c. (see CHEMISTRY) to form silicates. On the mass subsiding, fresh materials are added till the pot is filled with the molten glass.

The pots last for periods of greater or less extent —some for two, three, and even twelve months, while some give way during the preliminary testing to which all are subjected. When they are worn out, or give way, the operation of removing them and substituting new ones is one attended with considerable labour and excitement, and being carried on under the action of an intense heat, always excites the surprise of the spectator. When kelp was used, the operation of 'fritting' was necessitated, which consisted in stirring the mass under the heat of a reverberatory furnace; by which partial decomposition and the burning up of various impurities were effected. This preliminary operation is now dispensed with, owing to the use of soda.

The pots being now full of melted glass, the material is ready for the operations of the workmen. An iron tube, six or seven feet in length, thicker at one end than the other, is heated and dipped into the liquid 'metal.' A portion of glass adheres to the end of the rod, which, being

Fig. 11.

allowed to cool a little, is again dipped in, and gathers more. The rod is then taken out, and hung perpendicularly, that the metal may be equally distributed on all sides, and also that it may be lengthened out beyond the rod. The metal is next rolled upon a smooth iron plate, called the *marver*, and afterwards blown out slightly, so as to resemble a pear in shape. The blower then heats the metal twice, blowing it out between the heatings, when it is brought to a globe shape. The glass is then allowed to cool a little, and a rod of iron, called the *punty-rod*, is attached to the side immediately opposite to the tube. This is done by dipping the end of the rod in the liquid metal, which adheres readily to the half-cooled glass, and the tube is detached by touching it with a piece of iron dipped in cold water, leaving an aperture in the glass about two inches in diameter. The glass is again put into the furnace until it has become sufficiently ductile to yield readily to any impression. The workman then twirls the globe round, slowly at first, but afterwards with great velocity, during which the aperture formerly mentioned gradually widens, until it reaches a certain point, when the globe suddenly flies open with a loud ruffling noise, and becomes a plane or circular sheet of glass, about fifty inches in diameter. This is an exceedingly beautiful operation, and requires considerable skill on the part of the workman. The circular motion is still continued, until the sheet is sufficiently cool to retain its form, when it is carried to the annealing-arch to be tempered. The punty-rod is detached by means of large shears, and the sheet of glass is lifted on a wide-pronged fork, and set up edgewise in the kiln. A kiln will hold from 400 to 600 sheets. When full, the mouth is built up, the fire withdrawn, and the kiln allowed to cool as gradually as possible. This process of gradual cooling is known by the name of *annealing*—a process without undergoing which, glass, as well as several of the metals, would be so brittle as to break on the application of the slightest force. The glass is then taken out, the circular sheet cut into halves, and assorted into different qualities, known by the names of *firsts*, *seconds*, and *thirds*.

The glass thus produced is very rarely indeed of the best quality: it is generally characterised by more or fewer 'defects.' But even where a faultless 'table,' as the circular sheet is termed, is produced, the mode of manufacture prevents sheets of large glass being obtained. The wavy concentric lines at one time characteristic of this glass, are now not so common, through improvements in the details of the manufacture. But the distinguishing peculiarity of this glass—its beautiful brilliancy—is highly prized, and has had a decided effect in enabling it to withstand the formidable rivalry of the sheet-glass manufacture, to which we now direct the reader's attention.

Sheet-glass.

The process we have described is altogether applicable to crown or window glass; the manufacture of sheet-glass is somewhat different. In making sheet-glass, the same materials are used as in crown-glass, the difference being in the manner of forming the sheet. When the metal is melted, the workman dips his tube into the pot, and when he has gathered a sufficient quantity of the liquid glass upon it, he places it in a horizontal position upon a hollowed block of wood. He turns the rod round in his hand, with the metal resting upon the hollowed block, which forms it into a solid cylindrical mass. Water is poured upon the block during this operation, to prevent the burning of the wood and the scratching of the glass. If the glass was only red hot, on coming in contact with the water, it would crack; but at the great heat at which it must be kept so as to be ductile, no injury takes place. When the metal is sufficiently formed and cooled, the workman blows into the tube until he perceives the diameter to be of the dimensions required, which depends upon the size of the sheet to be made. The metal is again put into the furnace, and when softened, the workman swings it round his head, re-heats, and continues to swing it, until the cylindrical mass has attained what he thinks a sufficient length. He then fills the tube with air, at a slight pressure, by blowing into it, and closes up the hole, so that none may escape; after which the metal is again put into the furnace, and as it becomes soft, the air bursts from the end opposite to the tube, leaving an aperture. The cylinder is now turned round very quickly, which renders it perfectly straight; and then, by applying cold iron to the end of the glass next the tube, a sudden contraction takes place, which separates the cylinder of glass from the iron tube. The cylinder thus formed is allowed to cool for about five seconds, and is then split up lengthwise by drawing a diamond along the inner side. The glass has next to be flattened, which is done by softening it in a furnace upon a smooth plate, where, as it begins to melt, it gradually opens, and is smoothed with a piece of charred wood. It is then carried to the annealing-furnace to be tempered, in the same manner as crown-glass. The method above

described of making sheet or cylinder glass was introduced, in 1842, from the continent by the Messrs Chance. These gentlemen have effected many other improvements in the manufacture.

Sheet-glass may be made of any thickness, and possesses considerable advantages over crown-glass from the greater size of sheets obtainable. For the Great Exhibition of 1851, cylinders were blown yielding sheets 49 by 30, which were cut into panes 49 by 10. Of these, 300,000 in number, and 400 tons in weight, were made in a few weeks, and without disturbing the ordinary economy of the manufactory in which this large order was executed. Sheet-glass, however, is wanting in the brilliancy of crown, and has on its surface 'cockles,' which refract and reflect the 'light in various and contrary directions; and the objects seen through the glass are thereby distorted.' Mr Shaw gives the following as his notion of the cause of this defect:—'When the divided cylinder is softened by heat, and either allowed to flatten by its own weight, or flattened by the workman, the concave interior of the cylinder has to expand, and the convex exterior to contract as the curved surface becomes plane. Were this contraction and expansion to take place uniformly throughout the glass, the undulation in question would not occur; but since one part invariably yields somewhat more readily than another, perfect flatness cannot be attained.' To remove this defect, was for long the desire of manufacturers; in France and Germany, the sheets were made of greater thickness than required, and ground down to flatness. The introduction of machinery for grinding and polishing by Mr James Chance of Messrs Chance and Co. of Birmingham, effected quite a revolution in the trade in this country, and is characterised as one of the 'greatest improvements which has ever been introduced in the manufacture of glass.' By this means, large sheets are obtained, in appearance equal to plate-glass, and at a price very little above that of the old form. In Mr Chance's plan, each sheet of glass is laid upon a flat surface, covered with damp leather—'the sheet adhering completely to the leather, after having been pressed against it, producing in truth a vacuum, which maintains the whole sheet in a flat position. Two sheets having been placed in this manner, each on a retaining or sucking surface, they are turned against the other in a horizontal position, sand and water being constantly supplied between them; and by means of the most ingenious machinery, the two surfaces rapidly rub one against the other in all directions, and are ground at the same time by the sand.' The other sides are then subjected to the same process. A very thin layer only of the surface is rubbed off, the sheet lying so perfectly flat.

Plate-glass.

The manufacture of plate-glass requires greater care than either of the two preceding kinds, and the process is different—the plate-glass being moulded, and not blown, as is the case with other kinds of glass-ware. Two kinds of crucibles are required in the manufacture of plate-glass—namely, the pots in which the materials are melted, and the basins from which it is poured upon the moulding-plate. These crucibles are made from a clay entirely free from iron and lime, and which is dried, ground, picked, washed in water, and passed through a fine hair-sieve. Old crucibles ground to a powder are mixed with the clay in proportions according to its quality. This composition, when prepared, is called *slip*, and is also used for cementing the furnaces.

The materials of which the glass is composed are first put into the pots to be fused, which occupies about sixteen hours, and then transferred to the basins. The transfer of the melted glass from the pots to the basins is called *lading*, and is performed by ladles of wrought iron, furnished with long handles. This second melting is called *refining;* and the glass is allowed to remain other sixteen hours, which is necessary for the disengagement of the air-bubbles introduced by the transferring, and for giving the metal the proper consistence for casting. For three hours previous to the casting, all the openings in the furnace are closed—an operation called *stopping the glass*, or *performing the ceremony*. The glass is tried; and if found of the proper consistence, and free from air-bubbles, the basins are carried to the casting-table. This is made of cast iron, and on it the melted glass is poured, and flattened or rolled out by passing a roller over it. After being inspected, it is put into the annealing-furnace, in which it remains for fifteen days. When properly tempered, the rough edges are cut off with a diamond, and the plate is now ready for grinding and polishing. This is, in all large establishments, performed by machinery, and by a process very similar to that already described for sheet-glass. The grinding first levels the surfaces; emery is next employed to smooth, and wooden blocks, covered with layers of woollen cloth, to polish them. Patent processes are now in operation by which plate-glass receives a peculiarly dazzling metallic lustre, and by which elaborate ornamental designs can be imparted to its surface.

Plate-glass is extensively manufactured into *mirrors*, which has hitherto been done by applying a layer of tinfoil, alloyed with mercury, to the posterior surface of the glass. Various improved processes are now, however, in use for effecting the 'silvering' of mirrors; among others, we may notice the method adopted by M. Tourasse, which is an improvement on that patented by Mr Drayton of Brighton. By this plan, mirrors may now be made in a very short time, and of any shape. A solution containing nitrate of silver and other ingredients is poured on the plate, when after a time a deposition of silver takes place on the surface of the glass. The liquid is then poured off, and the silver, when dry, is protected by a coating of bees' wax and tallow.

Flint-glass.

Flint-glass, or crystal, is composed of Lynn sand—which is calcined, sifted, and washed for the purpose—red-lead, or litharge, and refined pearl-ash. It was formerly made of calcined flint, but the finest Lynn sand has been found to produce a clearer ware, and is therefore preferred.

A flint-glass furnace varies little from those described for other kinds of glass, except that it is round in the top. The pots in which the glass is melted have their tops arched over, that no dust may fall in, with a hole at the side near the top, for the insertion of the tube. When the glass is sufficiently melted, the tube is inserted, and a quantity lifted out upon its point, in the same manner as for crown-glass. After being rolled upon the marver, the glass is blown out to a globe-shape, when the punty-rod is attached, and by means of an instrument resembling a pair of sugar-tongs, the glass is moulded to the form required. The shapes into which flint-glass is manufactured are so numerous, that it would be almost impossible to describe them all. The operations are extremely simple and beautiful, and are performed with a rapidity which is truly astonishing. The workman is furnished with a pair of compasses and a graduated scale, to measure the articles which he is making, by which they are kept of a uniform size. When finished, the articles are all weighed, to see that the right quantity of glass has been used in their manufacture, and after this they are put into the annealing-furnace.

Optical glasses are made from crystal, in which case the utmost care is necessary to keep the metal entirely free from waves, otherwise the glasses will be useless. An *achromatic* object-glass for a telescope or microscope—that is, an object-glass which does not produce coloured fringes around the edge of the image—distinguished as chromatic aberration—must consist of two lenses made of different kinds of glass, differing in the proportion

which their refractive bears to their dispersive power. Flint-glass and crown-glass are well adapted for being formed into such a compound lens, the dispersive power of the former being nearly double that of the latter, while the mean refractive powers of the two kinds are nearly the same.

Bottle-glass.

Bottle-glass is composed of the coarsest materials, generally soap-boilers' waste and sand. The furnaces for preparing bottle-glass are similar to those used for crown-glass; and the raw materials are treated much in the same way. As the mixture always contains a very small relative proportion of the alkaline ingredient, its vitrification requires a high temperature; but it is usually complete in eighteen or twenty hours. After the undissolved matter has subsided, the *sandiver*, or 'scum,' which rises being skimmed off, and the glass cooled down to blowing consistency, the mass may be worked up into bottles. For this purpose, the workman introduces his tube, and when sufficient is gathered upon the end, he rolls the glass upon a stone, blowing into it at the same time. He then puts the metal into a brass or iron mould of the shape of the bottle to be made, and blows through the tube until it comes to the desired form. This mould is so contrived as to open down the middle by means of a spring which the blower works with his foot. The mould is open when he puts in the metal at first; it is then immediately closed, and opened again when the bottle is formed, which is handed over to the finisher. The finisher detaches the tube from the mouth of the bottle, and fixes the punty-rod to the bottom. He then warms the bottle at the furnace, and takes out a small quantity of metal, which is turned round the upper part of the neck, and forms the rim usually seen on bottles. The finisher next employs a pair of shears to give the right shape to the neck: on one of the blades of the shears is a piece of brass resembling a cork, by which the inside of the neck is formed. The bottles thus finished are sent to the annealing-arch, which is kept a little below melting-heat until full, when the fire is allowed to die out.

Cutting—Grinding—Etching.

The instrument universally employed in *cutting* window-glass is the diamond, which is set into a metal socket, attached to a wooden handle for this purpose. The cutting point of the diamond must be a natural one; artificial points, as well as those produced by breaking the diamond, only scratch the glass, without producing the deep cut which is necessary.

What is called glass-cutting, or *grinding*, is a separate trade from blowing in all glass-manufactories. The cutting-wheel is driven by means of a belt proceeding from a large drum attached to an engine or other moving power. Above the cutting-wheel is a conical box, from which wet sand drops upon it, while another is placed below, to receive the sand as it falls from the wheel. The wheels used are three in number: the first is made of cast iron, by which the rough glass is ground; the second, of Yorkshire stone, by which the vessel is smoothed; and the third, of willow-wood, by which the final polish is communicated. For this latter purpose, the wooden wheel is dressed with rotten-stone or pumice-stone; and for imparting the highest degree of polish, putty powder is used. These wheels are of various forms, according to the shape of the vessel to be cut. They may be broad or narrow, flat-edged, two-edged, concave, convex, &c. The cutter holds the glass to the wheel while it is revolving, and the most beautiful and regular figures are engraved in this manner with astonishing rapidity. Imitations of cut-glass vessels are made by blowing the soft glass into a polished metallic mould, the form of which it acquires with as much faithfulness as wax.

As stated under CHEMISTRY, the vapour of hydrofluoric acid acts energetically on glass, and is sometimes employed for the purpose of *etching* on this material. 'The art,' says Parnell, 'may be practised on all kinds of glass, but the most proper description is good crown-glass. The facts on which the art is founded are, that glass becomes powerfully corroded by exposure to the acid in question, and that certain parts of the glass may be easily protected by a resist varnish, on which the acid exerts no action, except at a high temperature.' A variety of processes are now in use for decorating the surfaces of glass ware; space prevents us, however, from noticing any of these; we refer the reader, therefore, to other and larger works, for a description of them.

Staining—Colouring—Enamelling.

The art of staining or colouring glass is believed to be coeval with the discovery of the article itself. It is certain that it was known in Egypt several thousand years since, and tradition gives the honour of the discovery to an Egyptian king. The art of combining colours so as to produce pictures is of more recent date. The early specimens of stained glass exhibit a number of different pieces of various colours, joined together like mosaic work, so as to bring out the representation desired. This can now be done on one entire sheet. For a long period, the pictured glass used in cathedrals, &c., was merely painted on the surface, and was consequently liable to be rubbed off. The colours now are incorporated by fusion, and cannot be obliterated but by the destruction of the glass itself. The discovery of this art is ascribed to a painter in Marseilles, who went to Rome during the pontificate of Julius II. It was afterwards greatly improved by the celebrated Albert Durer and Lucas of Leyden.

All the pigments used in painting on or staining glass are oxides of metals or minerals—as gold, silver, cobalt, manganese, &c.—which, after being laid on, are subjected to a strong heat, until they penetrate into the body of the glass, or become fixed on its surface, and thus give out their fullest brilliancy and transparency. Animal and vegetable matters, which are freely used as colouring in ordinary painting, are wholly excluded in this, as the operation of the fire would entirely destroy their colouring properties. The colours that are meant to penetrate into the glass for the purpose of staining it, are wholly transparent, while those which are merely fixed upon the surface are only semi-transparent. Any colour or tint can be communicated to the glass in this way, and the art is at present practised with great success. The description of glass best adapted for painting upon or staining, is the finest crown or window-glass.

'The substances employed'—we quote from Parnell's Applied Chemistry—'for rendering colourless and some coloured glasses more or less opaque, like enamel, are phosphate of lime, fluor-spar, arsenious acid, peroxide of tin, phosphate of lead, and phosphate of antimony. Phosphate of lime, which is the only one of these materials commonly employed at present, with the exception of fluor-spar, is introduced in the form of finely powdered calcined bones, to the amount of one-twentieth to one-thirtieth of the weight of the glass. A very beautiful opaline crystal is obtained in this way.'

The applications of glass prepared and ornamented as above are almost innumerable. Its use for windows, mirrors, bottles, decanters, drinking-glasses, and other vessels of domestic utility; for optical lenses, and the construction of chemical and philosophical apparatus; for decorative mouldings, chandeliers, and articles for the boudoir; for beads, spangles, gems, and other personal ornaments—must be familiar to every British reader. Since the abolition of the duty in 1845, its use has been extended in horticulture and in the dairy, and in a great variety of ways; and it is not too much to predict its application, on a large scale, to other

economical purposes for which, by its beauty and durability, it is so eminently adapted.

PASTES—ARTIFICIAL GEMS.

In gem-sculpture, *paste* is the term for a preparation of glass, calcined crystal, oxide of lead, and other ingredients for imitating gems. This art appears to have been well known to the ancients, and after being lost, was restored, at the end of the fifteenth century, by a Milanese painter. The general base of artificial gems is a vitreous compound known as the 'Mayence base' or Strass (from the name of its inventor). It is prepared, according to Fontanieu, in the following manner:—8 ounces of pure rock-crystal, or flint, in powder, mixed with 24 ounces of salt of tartar, are to be baked, and left to cool. The mixture is to be afterwards poured into a basin of hot water, and treated with dilute nitric acid till it ceases to effervesce; and then the frett is to be washed till the water comes off tasteless. This is to be dried, and mixed with 12 ounces of fine white-lead, and the mixture is to be levigated and elutriated with a little distilled water. An ounce of calcined borax being added to about 12 ounces of the preceding mixture in a dry state, the whole is to be rubbed together in a porcelain mortar, melted in a clean crucible, and poured out into cold water. This vitreous matter must be dried, and melted a second and a third time, always in a new crucible, and after each melting, poured into cold water, as at first—taking care to separate the lead that may be revived. To the third frett, ground to powder, 5 drachms of nitre are to be added; and the mixture being melted for the last time, a mass of crystal will be found in the crucible of a beautiful lustre.

A base being thus prepared, the peculiar colours are obtained from the metallic oxides, which, in proper proportions, under the hands of an experienced manipulator, are said to yield imitations so like the natural gems, that none but lapidaries or mineralogists could detect the deception. In general, the artificial products are softer, more readily scratched, and of less specific gravity than the real gems; while their power of refracting light is also different—a test that can be applied without unsetting them.

CEMENTS—ARTIFICIAL STONES.

Under this section we rank those compositions generally known as cements, mortars, concretes, plasters, and stuccoes. Their preparation, for the most part, involves a knowledge of chemical principles, and their practical application as ornamental mouldings, substitutes for sculpture, and the like, is an art as strictly fictile as the fabrication of earthenware or porcelain.

The *mortar* or cement employed to unite stones and bricks into a compact mass in building, is composed of quicklime, sand, and water. Quicklime is procured by roasting or calcining limestone in kilns, into which moderate-sized fragments of the rock are placed in alternate layers with coal or turf. By this process, water and carbonic acid are expelled, and the limestone converted into what is called *shell* or unslaked lime. The shells are then reduced to powdery quicklime by *slaking*—that is, by pouring as much water upon them as will suffice to destroy the cohesion of their particles. When intended for mortar, the quicklime should be immediately incorporated with sand, and used without delay, before it imbibes carbonic acid from the atmosphere. Lime, thus mixed with sand, becomes harder, and more cohesive and durable, than if it were used alone. The cement formed in this manner continues to increase in strength and solidity for an indefinite period, partly from the hydrate of lime being gradually converted into a carbonate partially crystallised, and partly from the formation of silicates.

When common mortar is made so fluid with water as to be poured on a course of brick or stone work, it is known by the name of *grout*. Where great strength and durability are required, the practice of grouting the hearting or packing of the walls is usually adopted; as by this means the interstices are filled, and the whole rendered, by the hardening of the lime, a solid compact mass. Foundation *concretes* are generally formed of small angular stones well packed and grouted. Such concretes are proof against all moisture and decay, and, on indifferent subsoils, form more resistant foundations than isolated blocks of stone, however large and heavy.

Hydraulic or *water cements*, also called *Roman cements*, are those which have the property of hardening under water, and of consolidating almost immediately on being mixed. Common mortar, although it stands the effect of water very well when perfectly dry, yet occupies a considerable time in becoming so, and dissolves or crumbles away if laid under water before it has had time to harden.

A great variety of artificial hydraulic cements are now in use, the best known of which we may here shortly describe. 1. *Portland Cement*.—This important cement is 'made from carbonate of lime, mixed in definite proportions with the argillaceous deposit of some rivers running over clay and chalk, pounded together under water, and afterwards dried and burned. The strength of the composition is very remarkable, being nearly four times as great as that of any other kind. Portland cement makes an admirable and most powerful concrete, the proportion of cement required being only a tenth or a twelfth part.' 2. *Parker's Cement*, known otherwise as compo, is much used for facing houses, water-cisterns, setting the foundations of large edifices, and the like, and is described as follows in the *Engineers' Journal*:—This valuable cement is made of the nodules of indurated and slightly ferruginous marl, called by mineralogists *septaria*, and also of some other species of argillaceous limestone. These are burnt in conical kilns, with pit-coal, in a similar way to other limestones, care being taken to avoid the use of too much heat, as, if the pieces undergo the slightest degree of fusion, even on the surface, they will be unfit to form the cement. After being properly roasted, the calx is reduced to a very fine powder by grinding, and immediately packed in barrels, to keep it from the air and moisture. For use, it is tempered with water to a proper consistence, and applied at once, as it soon hardens, and will not bear being again softened down with water. 3. *Atkinson's Cement* is made from the lias rock. Natural substances are also frequently used for the formation of hydraulic cement. Of these, *puzzolana* is the most notable. This was used by the Romans in building the foundations of their quays, artificial islands, &c. It was discovered at Puteoli, the modern Puzzuoli, near Naples, from which it is now chiefly obtained. This earth is a light, porous, friable mineral, various in colour, and evidently of volcanic origin; mineralogically, it may be designated a calcined ferruginous clay. When reduced to powder by beating and sifting, and thoroughly mixed with lime, either with or without sand, it forms a mass of great tenacity, which in a short time cements to a stony hardness, not only in the air, but likewise when wholly immersed in water. To give the composition greater tenacity, it is occasionally mixed with bullocks' blood and oil. *Dutch trass* is a somewhat similar substance, which used formerly to be imported from Holland, where it is extensively used in hydraulic works. It is made from a light vesicular lava found near Andernach, on the Rhine.

Plaster, or the material which is used to spread smoothly over walls, is of various kinds. That which is applied to inner walls or partitions, is formed of certain proportions of slaked lime, fine sand, and water, with mixture of cow-hair, to assist in giving cohesion. The best plaster is now prepared by the pug-mill, by which the ingredients are more thoroughly incorporated

than by the old process of hand-beating. Spanish white, ochre, and other colouring matters are added when any peculiar tint is wanted; but we may here remark, that the most durable of all plasters, and that which answers best even for fresco-painting, is composed simply of well-slaked lime and sifted river-sand. The surface of plaster is now seldom finished with a view to permanent exposure—whitewashing, sizing in colours, oil-painting, and, above all, papering being the prevalent fashions of the day.

Stucco is the name ordinarily given to plaster of Paris, which is gypsum reduced to a powder by heat and grinding; but the term *stuccoes* is further extended to embrace all those compositions with which walls are coated or ornamented, in imitation of stone. Gypsum, which is found in roundish hard masses, is properly a sulphate of lime; and, like all other varieties of lime, it has a strong power of absorbing water. The practice is, to put the masses into a heated oven, and when duly baked, to take them out, and grind them to powder in a mill. This powder, when sifted, is a beautiful white substance, resembling flour. A quantity of powder being put in a vessel, water is poured upon it, and immediately the stuff thickens in a surprising manner, and becomes a hardened mass. While still thickening or setting, it is poured into a mould for any required shape; or it may be applied along with a little lime as a fine plaster, which it is desirable should dry speedily. It is used largely for all kinds of casts from pieces of sculpture, mouldings for cornices, and for stereotyping. There are none of the artificial stuccoes which yield so sharp or delicate a cast; but most of them excel it in hardness and durability. Gypsum, or sulphate of lime, is the basis of all the cements known as Keene's, Martin's, Parian, &c. In these, the 'plaster in the state of fine powder is thrown into a vessel containing a saturated solution of alum, sulphate of potash, or borax. After soaking for some hours, it is removed, and air-dried, and subsequently rebaked at a brownish red heat.' It is finally reduced to a fine powder, which, when required for use, is mixed with a solution of alum. 'When borax is used, the plaster is called *Parian*, but where sulphate of potash is employed, it forms Keene's Cement. The kind called Martin's Cement is made with pearl-ash as well as alum, and is baked at a much higher heat than the rest.' All these cements are greatly used, and are particularly valuable 'when a hard durable substance is required, uninjured by damp, and perfectly safe from the attacks of vermin.' They are worked with great facility.

Scagliola is the Italian term for a composition intended to represent various marbles, porphyries, serpentines, &c. It is composed of fine plaster of Paris, with colouring matters, cemented by glue or isinglass, and is sometimes studded with chips of alabaster, &c., to imitate verd-antique. It is laid on like common stucco, moulded into the desired forms, and allowed to set. When thoroughly set, it is smoothed with pumice-stone, and washed; then polished with tripoli and charcoal; next with tripoli and oil; and finally with pure oil, laid on with cotton wool. The result is a surface of unusual richness; but from the nature of the ingredients, it is only fitted for internal decoration, and even then requires to be kept dry.

The material known as 'metallic lava' is a patented composition, capable of being moulded into forms of great variety; it is also well adapted for pavement in which mosaic work can be imitated.

Bituminous Cement.—This is best known by the name of Asphalte. Asphalte, or asphaltum, is a bituminous mineral, allied in its nature to pitch, and is found in the form of rocky masses in different parts of the world. For pavement, it must be mixed with sifted gravel, pounded iron slag, or river-sand, which gives it more stability, and a degree of roughness that is not unnecessary. The composition is prepared in portable boilers or caldrons, and spread while hot on a properly prepared bed; and being rendered smooth on the surface, it offers an exceedingly agreeable resistance to the foot, being not so hard as stone, nor so soft as a mud pathway. Wherever stone is expensive, asphaltic pavement may be advantageously employed, not only for streets, but floors of dairies and other outhouses, garden-walks, and terraces.

Mastic is properly a resinous substance obtained from incisions made in the branches of the *Pistacia lentiscus*, and received its European name from being chewed or used as a *masticatory* by women in Turkey, for the purpose of cleansing the teeth, and imparting an agreeable odour to the breath. But the term *mastic* is also applied —not very appropriately—to certain cements which are used for architectural decoration, and which it is not necessary here to describe.

Various *artificial stones*, besides those for ornamental purposes, have recently been brought under the notice of the scientific. From the attention bestowed on their production by practical men, and the best of them having for their object the utilisation of products now considered as refuse, there is every probability of the manufacture becoming an important branch of social industry. Before noticing these artificial stones, we shall glance at two methods of imitating the endless varieties of marble. The most celebrated of these is Magnus's enamelled slate. This material, from its comparative cheapness, its great strength, lightness, and the ease with which it can be worked into an endless variety of forms, is exceedingly well adapted for household and decorative purposes. And now that the method of imitating, through its means, the finer varieties of marble has been successfully established, its use will doubtless be greatly extended. The exact nature of the process has not been made public; but after the colouring is laid on, the slate is subjected to a temperature of from 310° to 500° for several days. By this means, the colours are rendered very permanent. Messrs Iles & Co. have invented an ingenious and cheap method of imitating marbles in hard and soft cement. The effect is produced by the waste materials of silk-works, or the short cuttings from piled fabrics, as cloth and velvet, mixed with the cement; the whole thus forming a mass having either a uniform colour or a mixture of colours throughout; while the veins are formed by silk threads drawn out to imitate such appearances as may be fancied. A great advantage in point of cheapness is thus obtained, and in some cases a polish can be produced during the laying on of the cement. The price per foot is 4½d. for hard cement, while that of scagliola of the plainest description is 6s. 6d., the durability of the one being quite as great as the other. We now proceed to notice the varieties of artificial stone which have taken a place as of recognised utility.

The first in point of date is the 'patent stone' of Messrs Ransome and Parsons of Ipswich. A soluble glass is first formed by boiling flints in caustic soda under pressure; this liquid cement is then ground up with equal parts of pipe-clay and powdered flint, and the whole intimately mixed with ten parts of sand. The putty-like substance thus obtained is moulded into any shape required, slowly air-dried, and finally kiln-burned at a bright-red heat. During the firing, an insoluble glass is formed, by the soda taking up more silica and alumina.

Although easily adapted to a variety of purposes, one objection to the use of this stone, is the efflorescence which in process of time disfigures the surface. One purpose for which it has been found to answer admirably, is the formation of porous filter-stones, which are supplied at a cheap cost. Scythe and grind stones have also been made of it.

We next notice the process of M. Kuhlman, which, according to the editor of the well-known continental scientific journal *Cosmos*, is 'likely to tend to the

production of a great and new industry.' The attention of M. Kuhlman has for some years been directed to the constituents of lime cements. An examination of these led him to believe that all limes, more particularly hydraulic limes and natural cements, contained quantities of potash and soda—the part which these substances played in stones and cements being, that they 'served to bring the silica to the lime, and thus to form silicates, which, by means of the application of water, solidified a portion of the mass, producing the formation of a hydrate analogous to that which takes place with plaster.' A variety of experiments enabled M. Kuhlman to produce with fat limes and a silicate of potash—10 or 12 of the latter to 100 of the former, the whole very well pulverised and mixed—limes possessing all the characteristics of hydraulic limes. Noticing thus the affinity of lime for silica dissolved in potash, M. Kühlman was led to direct his attention to its action on calcareous stones. Here the success of his experiments opened up a very wide and important field; namely, the conversion of masses of soft limestone or chalk into hard durable stone, susceptible of a high polish. 'Chalk, whether in an artificial paste, or in its natural state, plunged into a solution of silicate of potash, takes up, even when cold, a quantity of silica, which may be increased considerably by exposing the chalk alternately to the action of the silicious solution and the air. The chalk assumes a smooth appearance, a compact grain, and a colour more or less yellow, according as it is more or less impregnated with iron. The hardness, which is at first but superficial, penetrates by degrees into the centre, even where there is considerable thickness.' To harmonise the shades, the inventor uses with a very white chalk 'a double silicate of potash and magnesia. This is a vitreous substance which forms a brown solution, and which, when used in the process, causes a little oxide of manganese to be deposited in the artificial silicious paste.' Where ferruginous limestone is used, the too sombre shades are harmonised by using in the silicate solution a small quantity of 'artificial sulphate of barytes, which, in penetrating the porous stone, whilst it forms a layer of silica, remains fixed, entering into a state of chemical combination.' M. Kuhlman's researches into the harmonising of the shades of the blocks of stone thus obtained, led him to the discovery of the means of giving an almost endless variety of tints and shades to their surfaces. This he effects by the use of metallic sulphates. Thus, sulphate of copper gives a beautiful green tint; sulphate of manganese, a brown. From the cheapness of the material, and the ease with which it can be worked into a vast variety of shapes, 'this method of converting soft lime into silicious limestone is likely to become a great acquisition in the art of building.'

If there is one feature which distinguishes the practical science of the present day more than another, it is the endeavours, many of them eminently successful, which it makes to convert the waste or refuse results of one manufacture into the useful and valuable products of another. To the utilisation of one refuse product, which is produced in vast quantities, and, being difficult to be got rid of, at present entails a burden upon the manufacture, practical men are now directing their attention, and with every prospect of success. We refer to the 'slag,' as it is termed, or the molten mineral products of our iron-smelting furnaces. Some idea of the quantity available of this material may be obtained, when we state that for every ton of iron produced two tons of slag result; and that three millions of tons of iron are produced in this country yearly. To this must be added the slag resulting from other metalliferous manufactures. This slag has hitherto had no commercial value; on the contrary, ironmasters have to get rid of it at an extra cost, varying from 9d. to as much as 3s. 6d. per ton. One authority calculates that in this way are lost at least £150,000 yearly, not taking into account the loss of the material itself. What this loss is, may be estimated from what Dr Smith, the patentee of a new process for utilising the material, says of its commercial capabilities: 'In the utilisation of slag by the processes of refining, casting, pressing, rolling, moulding, and annealing, we can avail ourselves of the facilities afforded by the extremely liquid state to which the slag is reduced in the smelting-furnace, so that we have only to prepare suitable appliances to be able to impart to it any desired form, colour, or texture. According to the treatment which it receives, slag can be rendered brittle or tough, hard or soft, compact or porous, rough or smooth. It can be cast into as great a variety of forms, solid and hollow, as iron itself, with the superior advantage of being susceptible of the admixture and blendings of colour, so as to render it equal in brilliancy to agate, jasper, malachite, the variegated marbles, and other more valuable varieties of the mineral kingdom. When properly annealed, it can be made to acquire a surface or texture at least ten times as durable as that of marble, and is susceptible of a polish equal to agate or cornelian.' From all that we have learned of this material, the above description of its properties is by no means overdrawn.

Slag has long been used on a small scale for a variety of purposes, the material being simply withdrawn from the smelting-furnace, and cast into the desired form, without any other process. The patent of Dr Smith, which is now the property, we believe, of a public company, who intend introducing the material on a large scale, has reference to the refining of it to such a degree, that a high commercial value is given to it. The main features of the process consist in 'the use of *pure* slag in its most favourable molten condition—protecting it from all admixture of foreign ingredients or débris; carefully refining it, so as to secure a uniform homogeneous product; and subsequently, by appropriate machinery, casting, stamping, pressing, cutting, rolling, &c.' The process of annealing is a most important one, and requires to be performed with the greatest care.

The patent process of Nesbet and Elliott for the utilisation of slag is, compared with that above described, very simple, the slag being merely moulded on iron plates, and then annealed. Paving-flags made on this principle were put down in Paris some years ago, and are still in use. Experiments as to its resistance to crushing powers, shew that this material has a very high value. While the process of Dr Smith has more especial reference to the production of ornamental articles, that patented by Mr Elliott takes up the manufacture of articles of utility chiefly, as bricks, tiles, draining and sewage pipes, &c., for which, with due care in annealing, this material seems admirably adapted, from its 'absence of porosity and impossibility of decomposition.' It is not a little remarkable that, in consequence of the difficulty met with in persuading ironmasters to use the slag which is positively a loss and a nuisance to them, Mr Elliott in his later patents has been forced to use an artificial slag, which is obtained by the fusion of the common brick-earths, these containing all the elements of slag—as lime, silica, and alumina. For this purpose, reverberatory furnaces are employed, the waste heat from which is used for a variety of other purposes.

A species of artificial stone, invented by the Messrs Chance of Birmingham, is obtained by the fusion of the Rowley ragg or basaltic rock of Dudley. By annealing, this returns to the basaltic condition; and by rolling, remains vitreous like glass. It is applicable to decorative and constructive purposes, and is very cheaply made.

The subject of the production of artificial stone is of vast commercial and social importance, and now that this is recognised by practical men, we have no doubt that the difficulties attendant upon the various processes will be gradually overcome.

Moulding compositions for making architectural

ornaments in relief are now extremely common, and in most instances well fitted for the object in view. The substances chiefly used for this purpose are carton-pierre, papier-mâché, stamped leather, and gutta-percha. Carton-pierre is now very largely used. From its lightness, durability, and ease of application, it is peculiarly adapted for architectural decoration. It is composed of 'the pulp of paper mixed with whiting and glue. This preparation is pressed into plaster piece-moulds, backed with paper, and then, when sufficiently set, removed to a drying-room to harden.' The drying is effected in a few hours, which is a great advantage. When papier-mâché is used for relief ornamentation, its preparation differs slightly from that of the material when employed to make trays and other similar objects. Sheets of brown paper are glued together, and pressed into a metal mould, which gives the form required. This is removed, and trimmed up. A pulp of paper and resin and glue is then put into the mould, and the ornament again pressed into it, which takes up the pulp, &c., and gives a sharpness of outline. Stamped leather is now becoming much used for relief ornament. The leather, properly prepared, is stamped with the ornament through the aid of a hydraulic-press, which gives a high and sharp outline. The hollows in the back are then filled up with a composition, which prevents the ornament from subsiding.

Caoutchouc and *gutta-percha*, two remarkable substances of vegetable origin—to be afterwards treated at length—can scarcely be omitted in any account of modern fictile fabrics. The former, being highly elastic, reducible by heat, soluble only in certain liquids, and capable of chemically uniting with several substances, is applicable to a thousand purposes of utility and ornament. The same remark may be applied with equal propriety to gutta-percha, which is also soluble only in certain liquids, is reducible by heat, and though inelastic, is much more ductile and plastic than caoutchouc. In our textile fabrics, both now occupy a prominent part; while, as fictile materials, they may be formed into ligatures and belts, tubes, bottles, springs, boots and shoes, water-proof vessels, knobs and handles, ornamental mouldings, and used as ingredients in pavements and floorings of a very durable kind.

The most recent improvement in the caoutchouc or India-rubber manufacture is treating it with coal-gas tar. The product possesses some very remarkable properties, rendering it, amongst other things, easily moulded into a variety of shapes, possessing great strength. It is proposed to apply it even to the production of articles of furniture, for which it seems well adapted.

Decorative Design as applied to Fictile Manufactures.—In the application of decoration to our various manufactured articles, there is a great diversity of opinion as to what constitutes correct canons or rules of taste. To give even the briefest résumé of the various opinions, would occupy a far greater space than we can afford; we must therefore content ourselves with noticing the general principles which few are found to dissent from.

The primary design of every manufactured article is to serve some purpose of utility. The article may have no other characteristic whatever save that naturally belonging to the material and the form given to it, to serve the use to which it is to be put. But to please the eye and gratify the taste of the owner, other characteristics may be given to it; and these may be derived from an adaptation of the ever pleasing and graceful forms of nature, or of those conventional forms which have been used by ancient nations in the decoration of their edifices. This desire to ornament those things which surround us —the house which shelters, the clothes which cover us, and the household utensils we use—has been a characteristic of man in all stages of his civilisation; so much so, that it seems to be a natural want. In early times, the shepherd in his silvan hut might festoon its interior with graceful trails of the vine-leaf, and twine a wreath of flowers round the gourd out of which he refreshed himself from the crystal spring. The savage of the present day, in the isles of the sunny south, struts about with a piece of gaudy cotton print, with as much satisfaction as the London lady derives from her flaunting brocade. It is, then, of some importance—at least in a commercial sense—that this love of ornamentation, which we find so universally diffused, should be encouraged; and it is of great importance, in an æsthetic or artistic sense, that ornament or decoration should be carried out in conformity with principles calculated to promote correct taste, and to throw around even the most common article the grace of beauty and true elegance.

We have said that utility is the primary design of all manufactured articles; this, therefore, should never be lost sight of, but the ornament should always be subservient to the main design. Ornament has therefore been defined as the 'decoration of a thing constructed.' Thus a jug is designed to hold a fluid, and to allow of it being taken from and put into it with great ease; but if the form, or the ornament added to the form, be of such a kind that the jug cannot be used as a jug, it is merely an ornament having the shape of a jug. When we find articles, such as vases, having forms or ornament given to them entirely inconsistent with their known uses, we at once trace a want of truth in the design. From these considerations is derived the canon or rule, that 'ornament should arise out of, and be subservient to construction.' It is in this sense that architecture has been defined as 'decorated construction.'

The next point to be noticed is the *material* of which the manufactured article is composed. As each material has its characteristic peculiarity, which is inseparable from it, the design should be subservient to and aid in bringing out the characteristics of the material. 'The treatment and feeling,' it has been truly remarked, 'of true works of art must, and ought to take their tone from the materials employed.' Thus, iron and glass at once convey each a certain constructive peculiarity to the mind; and where we see an article of iron and one of glass having both the same peculiarities of design, we feel at once that an inconsistency has been perpetrated, and that both cannot be right. Again, silk has a certain distinctive character, and cotton another: to decorate both, therefore, in the same way would be wrong; one of the objects would of necessity be characterised by a want of truth. Hence is derived the canon, that 'ornament requires a specific adaptation to the material in which it is to be wrought, or to which it is to be applied.'

Ornament is derived from three sources: from natural forms, from the conventional scrolls used in the decoration of ancient architecture, and from simple geometrical figures. These, of course, are all resolvable into one source—that of nature; but it is convenient to arrange them as above. There are two great schools of ornamentists. One school hold that natural forms closely imitated are the best suited to the decoration of works of utility or art—that, in the words of one of its most eloquent followers, 'all the true nobleness of art had come from people loving nature in some way or the other, expressing their sentiments about nature; and exactly in proportion as the reference to nature had become *more direct*, the art became nobler.' The other school hold widely different views. Thus one of its ablest exponents gives the following:—'Flowers or other natural objects should not be used as ornament, but *conventional* representations founded upon them, sufficiently suggestive to convey the intended image to the mind, without destroying the unity of the object they are employed to decorate.' The government 'Department of Science and Art' takes this view, for one of the principles of decorative art published under its sanction is the following:—'True ornament does not

consist in the mere imitation of natural objects, but rather in the adaptation of their peculiar beauties of form or colour to decorative purposes, controlled by the nature of the material to be decorated, the laws of art, and necessities of manufacture.' To take up space in investigating which of the two schools, the 'natural' or the 'conventional,' is the correct one, would serve no useful end; at the same time, we may say that the middle course seems the best. There are certain natural forms which, applied to certain purposes, would be best adapted the more closely they were imitated; while for other purposes, a conventionalising would be in better taste. Everything depends upon the material to be ornamented, the way in which this material is to be manufactured, and the uses to which the manufactured article is to be put. It is manifestly erroneous to apply a close imitation of a natural form to an article the use of which conveys an idea altogether opposed to that which the natural form suggests. Thus when we see a gas jet issuing from a water-lily, or water-plants spread over the surface of a carpet, we are at once struck with the obvious inconsistency. But referring the reader to special works on design for further information on the points we have indicated, we shall proceed to offer a few remarks on the application of decorative design to the various fictile manufactures which form the subject of the present paper. Taking these in their order as we discussed them, our remarks will first have reference to ceramic manufactures—pottery and porcelain.

The first point to be attended to is utility. To give a form, for instance, to a vessel which prevents its being cleaned, or to put a handle to it in such a way as to prevent it being lifted, is a manifest absurdity; such absurdities, nevertheless, have been often perpetrated. The ornament should also be subservient to the purpose for which the vessel is used. Thus, where it is likely to be in frequent use, all ornament should be avoided which will render it difficult to be cleansed, or afford facilities for dust and dirt harbouring. The nature of the material will also dictate rules for its ornamentation. Thus brittleness will prevent ornament in high relief from being used: 'All projecting parts should have careful consideration, to render them as little liable to injury as is consistent with their purpose.' Again, the peculiar characteristics of the material should be preserved and brought out; hence the absurdity of applying a surface-colour which gives the idea of another material, as the metallic lustre we see often in common vessels, or one conveying the idea that the material is marble. 'Landscapes and pictures are almost always,' says Mr Redgrave, 'out of place in pottery; and it certainly is objectionable to cover the centres of plates and dishes with pictures and views, not only because it hides the surface which it has been before said it is desirable to retain, but because utility would be better served by the absence of any decoration on the part which receives the viands, to satisfy that sense of cleanliness only to be obtained by the white unchanged surface of the material. . . . . In the application of colour to porcelain and earthenware, the surface should never be wholly or indeed largely covered; the material has a purity that should be decorated, not obscured.'

In designing articles made of glass, due attention should be paid to the peculiar nature of the substance. Its transparency; its purity of surface, which, if tarnished by use, is easily restored by cleaning; its brittleness, which prevents its use for merely constructive purposes, as, for instance, where a weight is to be supported: all these should be considered in the design. The use to which the vessel is to be put, must also be considered. Our remarks on this point, in speaking of pottery articles, are applicable here as well. A great deal of bad taste is often displayed in ornamented glass. Its transparency is frequently marred by a redundancy of obscuration, effected by grinding, or it is rendered opaque by dead colouring, or imitations of other materials, as opal or metal. Its purity of surface is destroyed by an excess in cutting; and its absence of all constructive qualities forgot in its frequent adaptation to architectural decoration. On this latter point Mr Wallis very justly remarks: 'The inappropriateness of architectural details, the value of which as ornaments consists in their outline, and the effects resulting from a play of light and shadow, being applied *to*, and *in* a material in which the effects are obtained by a light in transition, is at once obvious, if that very simple but much neglected question as to the nature of the material to be used is even fairly asked and honourably answered.'

In the application of glass to *mere ornament*—meaning by this, articles not of everyday utility, as chimney-piece and drawing-room decorations—the peculiarities of the material are still more frequently ignored. Thus, colouring in rich tints, overlaying the surface with gilding, imitation of opal, papier-mâché, and porcelain, completely hide the peculiarities, and attach ideas to the material altogether wanting in truth.

As regards the form of the articles, that is the best which gives the idea of lightness and elegance. 'In all cases, elegance of form should be the first consideration, to which cutting, gilding, or engraving should be entirely subordinate.' The ornament, says another authority, should be 'so arranged as to enhance by its lines the symmetry of the original form, and assist its constructive strength.'

In the department of stained-glass decoration, much might be said, did space admit. There are two schools or modes of treatment—one, the oldest, in which the subjects were not treated pictorially, but composed with 'extreme monumental simplicity,' severe outline, and thoroughly flat treatment; the modern or continental school, in which all the characteristics of a picture, careful drawing and perspective effects, are attempted to be given. Each of these schools has its able advocates. Mr Ruskin's dictum is as follows:—It should 'always be remembered by the workman, that the use of a window was to let in light, and that the virtue of the glass in a window was to be transparent; and that all art which tried to represent it as opaque, as a picture instead of a window, was mistaken and absurd.'

Of the moulding compositions we have noticed, papier-mâché is the most generally used. As regards the received ornamentation of this material, Mr Redgrave says it is 'the most gaudily decorated of all manufactures, and seems quite beyond the pale of any just principles of ornament. . . . . At present, it is a mass of barbarous splendour that offends the eye, and quarrels with every kind of manufacture with which it comes in contact.' Many of our remarks in the next number will be found applicable to this material.

In drawing up the remarks in this and the following number on decorative design, as applied to manufactures, we have been much indebted, amongst other authorities, to Mr Redgrave, R.A., who has appended to the Jury Report of the Great Exhibition, a Report on Design, replete with instruction and suggestions of a highly valuable nature.

TEXTILE MANUFACTURES.

By *Textile Manufactures*—as generally defined—are meant those in which filaments of flax, of cotton, of silk, or of wool, are wrought into linen, cambric, calico, muslin, silk, satin, flannel, broadcloth, and the numerous modifications of these now so well known to every British reader. In the present instance, we extend the definition so as to embrace every variety of fabric—as paper, felt, straw-plait, and the like—essentially composed of vegetable or animal fibre. In the preparation of these, from the rearing of the raw materials to their ultimate stage as articles of utility and luxury, there is involved a vast amount of labour, of mechanical and chemical skill, of capital and enterprise—so much so, that, as a class, they rank second to none of the manufactures which come within the scope of our national industry. In the following pages, we aim at a very general account, seeing that complete details of any particular process would be not only inconsistent with our limits, but unintelligible without the aid of numerous diagrams, and also a certain amount of practical acquaintance with the subject under review.

LINEN.

Of the various textile manufactures, strictly so called, that of linen is the most ancient. In the oldest records of history, sacred and profane, mention is made of it; and the notices given of the fineness of its texture, are evidence of the degree of skill then displayed in its manufacture. The word *linen* is derived from the old name of the plant now called flax, which is preserved in *line*-seed, or *lin*-seed. Linen is cloth made of *lint* (Lat. *linteum*), which is the fibrous bark of the flax plant (*linum usitatissimum*).

The plant, which grows in temperate climates, and usually attains a height of from three to four feet, is an annual, having a slender, smooth, hollow stem, rising undivided till within a few inches of its full height; its several branches are then terminated by small blue flowers, to which succeed roundish seed-vessels, each enclosing ten smooth shining seeds, replete with meal and oily matter. As a crop, flax is cultivated less or more in most European countries, and succeeds best in a rich deep loam, with a good deal of moisture. That produced in Holland and Belgium is said to be best; but our chief supplies are obtained from Russia, Prussia, and other countries bordering the Baltic. Egypt, anciently so celebrated for its fine linen, is beginning to yield a portion of our supply, and promises well for the future.

From the cheapness of foreign flax, but chiefly on account of our farmers being prejudiced against it as an exhausting crop, its cultivation has been little adopted in Great Britain. In consequence, however, of the dissemination of practical information on points connected with improved culture, and the exertions of our agricultural societies, this prejudice against the flax-crop is fast disappearing, and its cultivation is taking the place in our agricultural operations to which its importance well entitles it. The soil found to be best adapted to the cultivation of flax is a sound, dry, deep loam, with a clay subsoil; draining and subsoiling of the land are important. The great point in the preparation of the land is to have it clean and free from weed, so that the root can penetrate the soil. The seed is sown broad-cast, and finished with the harrow and roller. The crop will be so much the more valuable if it is carefully weeded, as done in Belgium.

When the seeds are beginning to change from a green to a pale brown, is the best time for pulling the flax. Where the crop grows of different lengths, these lengths should be pulled and kept separately, uniformity in this respect being of great value in the after processes.

The process first gone through after pulling is *rippling*—which consists in pulling the stalks through a series of iron teeth eighteen inches long, placed within a distance of half an inch of each other. These are fastened in a block of wood, which is placed at the end of a plank or long stool on which the operator sits. The rippling deprives the flax of its seed-capsules, which, when thrashed, yield linseed, valuable as affording oil, and a refuse used for feeding cattle.

The next process is to obtain the flaxen fibre or lint free from the woody core, or *boon*, of the stem. This is effected by steeping the bundles in water till the boon begins to rot, in which state it is readily separated from the fibre. The operation is called rotting, or *retting*, and requires to be managed with great care, as by continuing it too long, decomposition might extend to the fibre, and render it useless; while by discontinuing it too soon, the separation could not be effected with sufficient ease. The time is generally determined by the nature and temperature of the water, and the ripeness of the flax—decomposition taking place more rapidly in soft stagnant water than in running streams, in which the retting is sometimes conducted. After being sufficiently steeped, the flax is spread out on the grass, to rectify any defect in the retting, and ultimately to dry it for the breaking. In some districts, it is the practice to conduct the retting entirely on the grass—a process known as dew-retting, in contradistinction to water-retting. This is a safer and less offensive method, but it requires much longer time, and in a country where land is valuable, would become very expensive. On the whole, the mixed method of retting is preferable—that is, to steep till decomposition of the boon is well advanced, and then to complete the process on the grass. It has been attempted to separate the fibre by machinery, without subjecting the flax to retting; but the article so produced has hitherto been rejected as inferior in quality.

To avoid the delays and uncertainty dependent upon the old processes of retting or watering, plans have been recently introduced, bringing the operation more under control, like the other processes of our manufactures. The methods which have been adopted, and are now working with success, are known as Schenk's and Watt's. By the first of these, the flax is placed in vats, in which it is kept down by means of strong framework. Water is allowed to pass into the vats, to become absorbed by the flax; steam is next admitted, till the temperature of the water is raised to, and maintained at, about 90°. Acetous fermentation ensues in a few hours; and after being maintained for about sixty hours, the decomposition of the gummy or resinous matter in the stalk is completed. The mucilage water is next withdrawn from the vat, and the flax taken out, separated and dried either in the open air or in desiccating rooms, according to circumstances. In Watt's process, the flax is placed in a chamber provided with a perforated false bottom; the top is double, and filled with water to act as a condenser. Steam being admitted to the case, the first result is the freeing of the flax from certain volatile oils. The steam, rising to the top of the chamber, is condensed by contact with it, and falls in showers on the flax beneath—a decoction of the extracted matter is thus obtained. In thirty-six

hours, the process is completed, and the flax, taken out, is passed between rollers in the direction of its length, which presses out the water and decomposed gum, and splits and flattens the straw. By this process, all that the plant takes from the land is saved—the seeds, the chaff, and the refuse water being available as food for animals.

Prepared by either of the plans, the flax is now ready to be freed completely of its woody particles. This is effected by *scutching*. Previous to this, however, the flax is passed through a *brake* or revolving rollers, in order thoroughly to crack the boon. The brake, worked by manual labour, consists of a frame, in the upper side of which are a number of grooves; a movable piece is hinged at one end, and provided with a similar grooved piece on its lower side, but so placed that the projections pass into the hollows of the lower. The flax, placed between these, and struck by bringing down the hinged part, is broken, but the fibre remains uninjured.

In the flax-breaking machine, the flax is passed through a series of horizontal fluted rollers; the flutes do not touch, thus preserving the fibre while breaking the boon. In Plummer's machine, five rollers are used, and the pressure on the flax is regulated by weights suspended to the axles of the rollers. Fig. 1 is a diagram illustrative of this machine; the flax to be broken is laid upon the table *f*, and passed between the rollers *a*, *b*; from these it is led by the curved plate *hh*, to the rollers *b*, *c*; from thence to *d*, *e*, and finally placed on the table *g*.

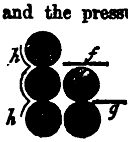


Fig. 1.

In continental countries, scutching is almost invariably performed by hand, the flax being held in a groove made in an upright stand, and struck by a flat blade. Machine-scutching is much more certain and expeditious than hand-scutching, and is, in consequence, fast superseding it in this country. After passing through the breaking-machine, the flax is subjected to the action of a series of knives, *b*, *b*, attached to the arms of a vertical wheel, *a*, fig. 2; these knives strike the flax in the direction of its length. A side view of the arms and knives is shewn at *c*, *c*, fig. 2. The process is

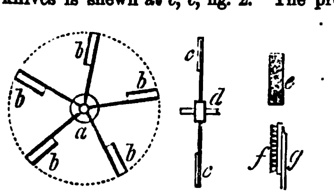


Fig. 2.

gone through three times before the flax is ready for the market. Although machine-scutching is expeditious, it is not capable of that pliant adaptation to the varying nature of the flax to be operated upon, which is obtained in hand-scutching. The effect of machine-scutching is to produce fineness by reducing and impairing, rather than sustaining, the character of the fibre—namely, the length and fineness of its 'staple' or fibre. To remedy these defects, Mr Plummer introduced scutching by means of revolving brushes, rather than by the hard unyielding blades or knives of the ordinary machine. In one form of machine on this principle, a series of flat brushes are arranged on the two faces of a disk, which revolves in a case. The flax to be operated upon is held in what is termed a *holder*, and receives from the brushes a succession of mild and penetrating strokes, which divide the fibre without tearing it. Mr Plummer has applied the principle to hackling machines with considerable success.

The diagram to the right of fig. 2 shews part of the disk, *g*, to one side of which brushes (of which one is seen at *f*) are attached: *e* is a front view of the brush *f*.

After being scutched, the flax is made up into *stricks*, or bundles, and taken to the next process, which is the first of what are strictly called the 'manufacturing operations.' The bundles are usually composed of fibres some twenty-six to thirty-six inches long; the part nearest the ends is of least, that nearest the centre of the fibre of the highest, value. To obtain the most valuable portion of each strick, it is separated into three, sometimes four parts, by means of a machine, of which fig. 3 is an illustrative diagram. In the centre of the framing, a wheel, *aa*, is supported on a shaft or axis; the periphery of this is furnished with a series of projecting or cutting edges of an elliptical form.

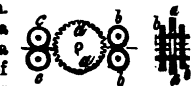


Fig. 3.

On each side of this cutting wheel, two pair of grooved rollers, *bb*, *cc*, revolve. An end view is given to the right of the cut, in which only the set of rollers at one side, *b*, *b*, are visible. The stricks are held stretched between the adjacent pairs of rollers, *b*, *b*; and the revolution of the rollers advances the flax sidewise against the cutting edges of the wheel, so that it is divided into two lengths, the one, however, being shorter than the other. The longer of the two parts is passed through the machine a second time, and thus each strick is divided into three lengths, of which the middle portion is more valuable than the two end portions. The three lengths thus obtained are laid on separate heaps, to be ready for the succeeding process of *hackling*.

The object of this is thoroughly to clean the fibres of all dirt, and to parallelise them, the cleaned portion being termed *line*, the refuse *tow*, which last is used for coarse sacking, &c. Hackling, as performed by hand, is as follows:—The hackle is a strong comb, composed of several rows of steel teeth, four or five inches in length, fixed upright in a block of wood as a base, and made fast to a bench, fig. 4. The workman taking a handful of scutched flax, strikes it against the pointed summits of the teeth, and draws it through—repeating the process till the requisite fineness is obtained.

Fig. 4.

Coarser and wider-toothed hackles are first used, and then others progressively closer as the fibres become finer by separation.

The process, however, is now almost universally effected by machinery, the nature and operation of which may be briefly described. The hackling-points are arranged in bands, or alternate rows, *a*, *a*, fig. 5, round the circumference of a cylinder, *bb*; the rows of points are of different finenesses—the row at one end being coarsest, the next finer, and so on. The flax to be operated upon is suspended above the cylinder by means of a holder, *c*.

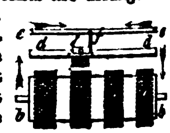


Fig. 5.

The process is threefold—first, as the end of the strick of flax depending from the holder is required to be hackled less than the middle portion, the strick is made to rise from, and approach to, the hackling-points; as the strick falls, the hackling-points pass through the ends, obtaining a deeper hold the lower the strick descends, and the thicker portion comes in contact with the teeth; and *vice versâ*. The strick is made to rise and fall as thus described, by placing the holder which carries it upon a *table*, *dd*, which, by means of a cam-movement, is made to rise and fall as desired. The second movement desiderated, is the pushing of the holders with their stricks along the table, to put the flax successively in contact with the rows of hackle-teeth of different gradations of fineness. This is effected in a variety of ways by ingenious machinery, for a notice of which we refer the reader to the *Artisan* for 1851, in the October and following numbers. One method adopted is illustrated in fig. 5. The rod *ee* has an alternate lateral movement, as shewn by the arrows; fingers, one of which is shewn at *f*, are jointed to the under side of this, and hang downwards. They are prevented from

moving in one direction by means of a snug or projecting part attached to *ee*. As the rod *ee* moves in one direction, the fingers give way, and slide over the top surface of the holders; but on its moving in the other direction, the fingers come in contact with the ends of the holder, and being prevented from moving by the snug above mentioned, they press against the holders, and move them along the table *dd*. The third movement required is to place the flax so that both sides of the strick shall be subjected to the hackles. As the hackles revolve always in one direction, it is necessary to turn the stricks after passing through the machine, before sending them a second time through. This, in many machines, is effected by hand; but in Carmichael's, the strick is made to give a semi-revolution by ingenious mechanism; while in Plummer's patent machine, both sides of the strick are hackled at once, by allowing the strick to be suspended from the holder, *c*, between two revolving cylinders, *a*, *b*, fig. 6, in the peripheries of which are fixed a series of brushes.

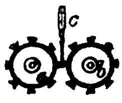


Fig. 6.

The flax is next passed through the 'spreading-machine'—the object of which is to bring the fibres into the condition of a long, narrow band, of uniform thickness. As the stricks from the hackling-machine are of different thickness, they are spread upon a table, *c*, fig. 7, the thin part of one being placed against the thick part of another. The sheet of flax thus prepared is passed between a pair of rollers, *a*, *b*, on to a series of upright hackle-teeth, represented by the line *h*, which have a progressive movement from the front to the back of the machine; these teeth still further comb and parallelise the fibres as they are moved onwards to a second pair of rollers, *d*, *e*, which, revolving faster than the first, *draw* out or lengthen them. The thin sheets of flax from the different rollers are passed in fours through slits made in the back plate of the machine, and being united into one, are finally passed between a pair of rollers, *f*, *g*, and delivered to a tin can. The progressive movement of the hackle-teeth, represented by the line *h*, in fig. 7, is effected by two methods, one of which is known as the 'sheet,' and the other the 'screw' 'gill.' The operation of the latter, which is considered the most effective, is illustrated by the diagram in fig. 8. On each side of the spreading-machine, fig. 7, two endless screws revolve in bearings one above the other, as 1, 1, 2, 2. There are thus two pairs, one on each side. The upper and under screws are placed parallel to one another, as *aa*, *bb*, fig. 8. Bars, as *c*, *d*, are so made as to pass at their extremities between the threads of the screw, and are thus made to progress in the direction of the length of the screws, as at *f*. The upper surfaces of the bars are provided with hackle-teeth. As each bar arrives at the end of the screw, it drops down to the position of 2, 2, fig. 7; the lower pair of screws revolving in the opposite direction, take the bars in the direction of the arrow *g*, fig. 8; on reaching the end, they are lifted up to the upper pair of screws—as 1, 1, in fig. 7. By this means, a continuous array of hackle-teeth is made to pass along between the rollers *ab*, *de*, fig. 7. The subsequent processes of *doubling*, *drawing*, and *spinning* are all nearly the same as in the cotton manufacture, afterwards described in this paper. The only difference is, that in spinning flax the slivers are previously passed through hot water of 120°; this is necessary, as they have not the same tendency to combine as the fibres of cotton. Weaving being a process common to all the textile fabrics, of the nature of cloth, will be described when speaking of the woollen manufacture.

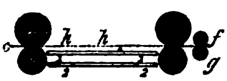


Fig. 7.

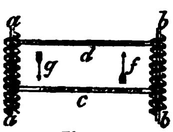


Fig. 8.

The *tow*, which may be termed the refuse of the manufacturer, being somewhat analogous in nature to *cotton*, is prepared by machines resembling those used for this material.

In the majority of flax-mills, the operations cease with the spinning of the fibres into the yarn, and the weaving is effected elsewhere, chiefly by hand-looms; although there are many factories in which linen-cloth is manufactured by the aid of the power-loom.

The chief seats of the linen-cloth manufacture are, Belfast in Ireland, Barnsley in Yorkshire, and Dundee and Dunfermline in Scotland. In Barnsley, the fabrics manufactured consist of linen, huckaback, diaper, duck, check, drabbet, tick, towelling, and union, a mixture of the staple with cotton. The fabrics made in Ireland are coarse and fine linens, canvas, sacking, and damask. The manufactures at Dundee are mostly confined to coarse linens, sailcloth; while at Dunfermline, fine shirtings, damasks, and table-cloths, &c., are the principal fabrics made.

Bleaching and *calendering* are the processes which follow the weaving, and in both there are now great improvements. The principles of bleaching have been already explained under APPLIED CHEMISTRY—whether by the old process of sun-bleaching on the grass, or by the application of chemical detergents. The following is a brief description of the process as followed by the Irish manufacturers. Taken from the 'pieces' which come from the manufacturer, and loosely knotted, the cloth is passed into a boiler or vat, along with a weak solution of potash. Boiled for several hours, it is transferred to a wash-mill, and subjected to the action of a stream of water, constantly passing through. The cloth is worked up and down in the mill by heavy wooden stampers, having an alternate motion given to them by means of a revolving cylinder furnished with projecting pegs, which lift the stampers up at intervals. From the mills, the cloth is removed to the green, and spread out, the lengths being roughly stitched together. They are retained in their place on the ground by means of pins. Allowed to lie here for two or three days, the cloth is again subjected to a series of boilings and washings. It is then passed through the 'rub-boards,' the surfaces of which are provided with hard wood cut into parallel grooves. The boards are moved backwards and forwards by simple mechanism, with the linen between them, plentifully soaped. The entire web is thus submitted to friction. The cloth is next steeped in vats, in a solution of weak sulphuric acid. The finishing processes then commence, which vary according to the fancy of the manufacturer—some smoothing by heated cylinders, others using starch and similar ingredients to stiffen the fabric, and not a few employing more objectionable methods of stretching, smoothing, and producing an artificial gloss, with a view to make an inferior fabric assume the appearance of one of superior quality.

Before concluding this part of the subject, we think it right to notice the important innovation in flax manufacturing introduced by Chevalier Claussen, well known as flax-cottonising, and which, although it has not yet been very successfully carried out, bids fair, in the opinion of competent judges, to form an important feature in our manufactures, when once experience has dictated improvements in the process, and the commercial and other difficulties always attendant upon the introduction of any innovation been fairly overcome.

The flax is in the first instance passed through a machine, which separates the woody core, leaving the fibres still held together by the gummy resin; from which they are next freed by being boiled in a weak solution of caustic soda. Where the fibres are required to be long, for manufacturing by ordinary flax-machinery, the flax is subjected to the action of a bath of weak sulphuric acid, which removes the alkali of the previous operation. It is then bleached. If it is desired to be adapted for spinning by cotton-machinery, so as to be

mixed with cotton, wool, or other fibre, the following processes are gone through:—The long flax fibres are cut into short lengths by a machine similar to a chaff-cutter. Taken out of the soda-vat already mentioned, the short lengths are next placed in another, containing a solution of bicarbonate of soda; remaining in this till fully saturated, the flax is taken out and subjected to the action of weak sulphuric acid. The result which ensues is singular. The hollow fibres saturated with the salt are brought in contact with the sulphuric acid; carbonic acid gas is immediately formed, and a series of explosions, as it were, take place, which split or blow up the fibres into beautiful filaments, closely resembling raw cotton. The material thus obtained is well adapted to be worked up by cotton machinery; and mixes well with cotton, wool, and silk, and takes, in addition, dye with considerable facility. A variety of useful mixed fabrics can thus be made. If the results held out by the advocates of this process can be realised, it will have an important influence on the cultivation of flax in Great Britain.

Prior to the introduction of machinery, the linen trade was very limited in extent. On the introduction, however, of improved mechanism, it increased rapidly. Mr Marshall stated that the trade had doubled in England, and trebled in Scotland, in the course of half a century. In 1850, the exports of linen-yarn amounted to £887,295. The importation into this country of flax and tow, in 1850, amounted to 1,821,578 hundredweights. In 1852, the consumption of flax fibres was about 150,000 tons, of which it was calculated that not more than a fourth was grown at home.

According to the Return of the Board of Trade, the declared value of the exports of the linen manufacture in 1852 was £4,231,786, and in 1853, £4,761,252. Linen-yarn was exported in 1852 to the extent of 23,928,592 pounds, value £1,140,565; in 1853, the number of pounds was 22,782,661, the value, £1,149,103.

The most recent Factory Return, of date 15th August 1850, presented to parliament, states the number of flax factories in the United Kingdom at 393—of which England and Wales possessed 135, Scotland 189, and Ireland 69. The number of spindles in the 393 factories amounted to 965,031, and the power-looms to 3660, absorbing a power of 10,905 horses in steam and 3387 in water power. The total number of hands employed was 68,434; of which 47,617 were females, and 20,817 males.

Hemp and other Ligneous Fibre.

Hemp is the fibrous bark of the *Cannabis sativa*—a plant supposed to be a native of Persia or India, but which has long been naturalised and extensively cultivated in Europe, particularly in Italy, Russia, and Poland, where it forms an article of primary commercial importance. It is also cultivated to a considerable extent in many parts of America; but in Britain it is but little grown, except in a few districts of Suffolk and Lancashire. Its fibres are prepared for spinning in the same way as flax, and are made into yarn for the fabrication of canvas-bagging, sailcloth, ropes, and cordage. The common cultivated *hop*, some species of *nettle*, and other plants belonging to the same natural order (*Urticaceæ*) as the hemp, yield also a tough elastic fibre, from which coarse fabrics are occasionally woven. Indeed, the elaboration of a tough elastic product seems to be characteristic of the whole order—making its appearance in the stem of the hemp, in the inspissated sap of the India-rubber tree, and in silk, the best of which is derived from silk-worms that feed on the leaves of the mulberry. Several of the members of another natural order (*Liliaceæ*) yield fibre strong enough to be worked into cloth and cordage; but in these the fibre resides in the leaf, and not in the bark of the stem. Of these may be mentioned the *New Zealand Flax* (*Phormium tenax*), whose toughness rivals that of hemp, and the *Sansevieras*, from which is obtained the still stronger substance called *African* or *bowstring hemp*. *Coir*, which is extensively worked into mats and cordage, is the dry fibrous pericarp of the cocoa-nut. The inner bark of various trees is sufficiently tough in fibre to form material for fishing-lines, nets, rice-bags, a coarse kind of linen, and the well-known matting called *bast*. The linden-tree may serve as an example, its inner bark furnishing the Russian or bast mats so largely employed for commercial purposes. The most of the coarse fabrics so composed are either woven or plaited; ropes and cordage are twisted on the same principle as common thread, either by hand-labour, or perhaps now more generally by machinery.

COTTON.

The cotton-plant is of the order *Malvaceæ*, its type being the common mallow. The genus *Gossypium* is that which produces cotton, comprising, according to various authorities, from five to ten species, all natives of intertropical climates, and indigenous to India and America. The numerous varieties of these species have their origin in peculiarities of soil, climate, or locality. The most useful species, and the one generally cultivated, is the *Gossypium herbaceum*, or herbaceous cotton-plant. It is an annual, the average height being twenty inches. Each leaf is divided into five lobes, the colour darkish green, streaked with brown veins. The flower is of a palish yellow, like the mallow; the petals are five in number, each having a purple spot at the base. On the flower falling off, a capsular pod is seen supported by three triangular leaves, having deeply indented edges; the pod is triangular in shape, of the size of a walnut, and is divided into three cells. As the pod ripens, the expanding wool bursts it, and exposed to view appears a ball of yellowish or snow-white down, which is divided into three parts, a part belonging to each cell. When thoroughly ripe, the operation of gathering is carefully gone through. As the plants do not ripen uniformly, the operation of picking has to be repeatedly gone through, warm fine weather being always chosen, never wet or damp. After being picked, the cotton or wool, as it is called, is laid to dry in the sun.

The qualities of cotton used for manufacturing purposes are various; the most valuable is that known as 'Sea Island,' which is cultivated on the low marshy islands and plains on the coast of Georgia and South Carolina, in the United States of America. The staple of this quality is long and silky. The short-stapled quality, known as Bowed or Upland Georgia, is produced in immense quantities in America. Cotton of good quality is imported from Egypt, where its cultivation was begun by Mehemet Ali in 1823. The supply obtainable from the East Indies is fast increasing in amount: when railways and canals open up the interior of our possessions there, and when as much care is taken in its cultivation and cleaning as is done in America, we may reasonably expect that our manufactories will be supplied to a large extent, if not exclusively, from these our own possessions. The West Indies also supply us with cotton. Brazilian cotton was first imported in 1781. Pernambuco cotton is very valuable, generally fetching a price next to that of Sea Island.

The value of cotton for manufacturing purposes is reckoned by the length, strength, and fineness of the staple, or fibres. The 'long-stapled,' or valuable cottons, are Sea Island, Brazilian, West Indian, Egyptian; the 'short-stapled,' or inferior qualities, are the Upland cotton of America, the Orleans, Mobile, and Surat.

Within the limits of our paper, it is impossible to trace the early history of the manufacture in the land of its birth in India, its extension to Arabia, to Spain, and ultimately to England. It is to a brief notice of its progress in this our own country that we will devote the short space at our command.

Some statements occurring in our early chronicles, would make it appear that an antiquity of 300 years

could be claimed for our English cotton trade. In Leland's *Itinerary* (1538), mention is made of the *cotton* trade of Bolton; and in a statute of Henry VIII., of that of Manchester. It appears, however, that these allusions had reference to woollen manufactures; as in sundry documents mention is made of processes in reference to *cottons* which are applicable only to woollen. Authorities conceive that the reason why *woollen* goods were termed '*cottons*,' was in consequence of the fabrics which they imitated being of foreign manufacture and made of cotton.

The first authentic proof we have of the existence of the cotton manufacture in England, is a notice in a work published in 1641, in which the existence and importance of the trade, as carried on at Manchester at that period, is specifically mentioned. The progress of the trade was remarkably quick; in 1727, the population of Manchester, then, as now, the seat of the manufacture, had doubled.

In 1697, the quantity of cotton imported was about 2,000,000 of pounds; it took fifty years to increase this to 3,000,000; the next fifty years shewed a more satisfactory rate of progress, the importation at the end of that period amounting to 56,000,000. In 1850, the quantity imported amounted to nearly 525,000,000. In 1785, the first bag was brought from America. The quantity obtained from that country in 1850 was nearly 2,000,000 bales. A bale weighs, on an average, 300 pounds, the price per pound varying from 7¼d. to 5½d. The average weekly consumption of the whole kingdom may be set down at 30,000 bales. In 1679, the total value of cotton goods exported was nearly £6000; in 1850, it reached a grand total of upwards of £28,000,000; and for the *seven months* ending August 1854, the declared value of cotton goods of all kinds exported was no less a sum than £18,601,374, or at the rate of £36,000,000 a year.

The introduction by Arkwright of the method of spinning by rollers was the turning-point in the history of the trade. Previous to this, the demand for yarn for weaving was always greater than the supply. But with the unlimited supply of the new process came also the increase of weaving. In 1850, the number of spindles at work throughout the kingdom was 21,000,000. In 1803, the first practical power-loom was introduced by William Horrocks of Stockport. In 1817, about 2500 only were in use; in 1835, this had increased to 116,801; and in 1850, to 225,000. In 1760, the manufacturing population was estimated at 40,000; in 1835, it had increased to 260,198; and in 1850, reached 332,124. In 1833, the number of mills in the kingdom was 1154, taking up a power of 41,000 horses in steam-engines and water-wheels. In 1839, the number of mills had increased to 2019; the horse-power to 59,856.

According to the Factory Return already quoted in the section on flax, the number of cotton-factories in the United Kingdom was 1932—of which England possessed 1753, Ireland 11, and Scotland 168. The amount of horse-power in steam employed in the 1932 factories was 71,005, and in water 11,550, giving motion, amongst other machinery, to 20,977,017 spindles, and 249,627 power-looms. The number of males employed was 141,491, and females 189,423.

We now proceed to detail the practical processes of the manufacture. The first of these we notice is that of separating the seed from the cotton, which is always done in the country in which it is raised. In America, the cleaning is effected by the roller-gin and the saw-gin. The first is a simple arrangement of two rollers having fluted peripheries, revolving nearly in contact. The cotton is passed between these, and the seeds, separated, fall down. Fifty pounds per day is the maximum amount of work of which this machine is capable. The saw-gin is the most efficient mechanism; and, from the immense amount of work it is capable of doing, it has had the same influence in extending the cultivation of cotton in America as the spinning-rollers had in extending the cotton manufacture in this country. The cotton to be cleaned is put into a hopper, *a*, fig. 9, the bottom of which is sloping, and is composed of bars of iron, *bb*, an eighth of an inch apart. Between these a series of circular saws, *c*, fitted on a roller, revolve; the teeth projecting a little above the bars, catch the cotton, and tear it open, the seeds sliding down the grating. The wool is stripped from off the saws by a brush, *d*, revolving rapidly against the teeth, and in the opposite direction to that of the saw. The cotton thus cleaned, is pressed into compact bales by the hydraulic or a screw press, and thus shipped.

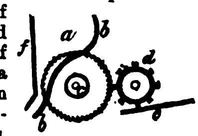


Fig. 9.

Arriving in England in a state far from clean, being mixed with a variety of extraneous matters, and the fibres much matted together, the cotton has to be further subjected to a cleaning process. This is effected by the *willow*. A large conical drum rotates rapidly on a horizontal shaft, and is provided with a number of projecting spikes; the drum is covered with a case, in the inside of which are a number of spikes, so arranged as to pass between those in the drum as it revolves. The cotton is fed by an endless *apron*, at the smaller end of the cone, and is dragged between the spikes up to the larger end, where it passes into a case, from whence it is withdrawn by hand. The rapid rotation of the cone creates a sufficient draught to carry off the dust through a pipe. A machine called Hardacre's cotton-opener is becoming much used instead of the willow. Two vertical shafts, *aa*, *bb*, fig. 10, rotate rapidly within a case, the sides of which have openings, leading the dust, &c., to a series of cells. The vertical shafts are provided with horizontal arms, which rapidly strike and open up the cotton, which is fed from the top, at *d*.

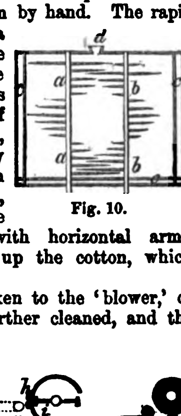


Fig. 10.

The cleaned cotton is now taken to the 'blower,' or 'scutcher,' fig. 11, where it is further cleaned, and the fibres separated one from another. The cotton being fed by the apron, *a*—made of a series of thin narrow wooden bars, fixed at their ends to two strips of leather revolving round rollers at each end—it passes between two pair of feed-rollers, *b*, revolving nearly in contact. On issuing from between the last of these, it is struck violently by the arms of a rapidly revolving beater, *c*, making some 1800 or 2000 revolutions per minute. The impurities pass from the cotton, and fall upon an inclined grating, *ee*, the cotton being wafted along to a second apron, *gg*, with a second set of feed-rollers, *h*, and again struck by revolving beaters, *i*, and finally passed to the floor. It is next taken to a second blower, similar in all respects to the former, excepting that instead of being delivered to the floor, it is passed through feed-rollers, *k*, and finally wound upon large rollers in the form of a continuous lap, *l*; hence the name of the machine, the lap-machine. In many cases, however, the blower and lap-machines are combined in one. The grating already mentioned is composed of thin bars of iron, set angularly, so as to present a series of edges to the cotton as it is whirled about by the beaters, thus further opening it. Between the first and second

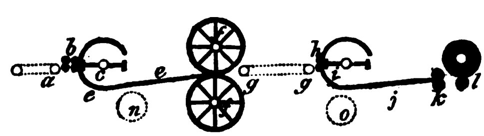


Fig. 11.

beaters, *c*, *l*, are two revolving hollow cages, *f*, *f*, with perforated periphery; the cotton is wrapped round this before being delivered to the second feed-rollers. A strong draught is created in the machine by fans, *n*, *o*, which aid in carrying off all the dust, &c., to the external atmosphere.

The action of all machines noticed has been to open the fibres of the cotton, and clear them of adhering matter. This, however, has brought about a condition of matters not desiderated in the after processes—namely, a complete confusion of the fibres, causing them to lie in all directions one to another. It is the duty of the following machines to bring all the fibres parallel to one another. The more complete the parallelisation, the higher the quality of the yarn obtained.

If the reader will take a quantity of loose fibres of cotton, confused and twisted together, and place them between two brushes, and move the brushes parallel to one another, but in opposite directions, repeating the process several times, he will find the fibres lie parallel to one another. This is exactly the carding process. The teeth of the brushes or cards are, however, fixed upon revolving surfaces, and are not straight, but bent, as *a*, fig. 12. The revolving teeth act against the teeth of other cards fixed on a curved surface, and the inclination of which is in an opposite direction. There are two arrangements of carding-engines in use. In the first, a large cylinder, *bb*, fig. 12, rotates rapidly, provided on its surface with a series of strips of leather, in which the wire card-teeth are fixed. These rotate in close contact with a series of cards called flats, *c*, *c*, fixed in the inner side of the outer casing, which is of the same curve as the large cylinder. In the second arrangement, the large cylinder is retained; but it works in contact with a series of small cylinders, provided with card-teeth, which rotate less rapidly than the large cylinder: these are termed squirrels or urchins, or strippers and clearers. The flat and urchin systems are sometimes combined in one. The operation of the carding-machine on the combined system is as follows:—

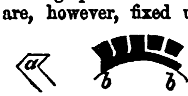


Fig. 12.

The lap-roller, *b*, fig. 13, with its length of cotton-lap wound round it, is placed at the end of the machine, in bearings—the lap is withdrawn from this by two feed-rollers, *c*; it is then taken up by a small cylinder, *d*, furnished with card-teeth, and called the 'licker-in;' from this it is taken up by the large carding-cylinder, *a*, and delivered to the small strippers, *f*, *f*, which, rotating with less speed, hold the fibres to allow the large cards to act upon them; the flats, as *c*, *c*, fig. 12, also take the fibres up, the process being a continual delivering and redelivering from the large cylinder to the small ones and the flats. The cotton is ultimately taken from the large cylinder by another, termed the doffing-cylinder, *g*, on which the cards are fixed in spiral lines. To take the cotton from this is the work of the doffing-knife, which is a long flat blade, with one edge serrated, fixed at the ends to two connecting-rods, *h*, which have a quick up-and-down motion given to them by cranks at their lower extremities. The action of the knife is to strip off the cotton from the doffing-cylinder, in a sheet of extreme lightness. This is gathered up, passed through a trumpet-mouth, *o*, and finally between revolving rollers, *m*, so as to form the cotton into a long, flat, and narrow ribbon, which, by means of ingenious mechanism, is coiled into long narrow cans, in such a way as to occupy the least possible space. Two kinds of carding-engines are used in the manufacture—the breaker and the finisher. In the former, the cotton, after being carded, is delivered to rollers, and finally wound in a continuous sheet on a lap-roller. This 'lap' is carried to the 'finisher' carding-engine, through which it is passed, and finally coiled in the can, as above described.

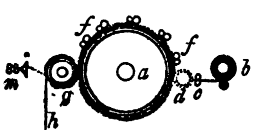


Fig. 13.

The next process is that of 'drawing,' the object of which is still further to parallelise the fibres. Let a tuft of cotton fibres be taken, and separated by means of the fingers; by repeating this process for some time, it will be found that the confused fibres will lie parallel to one another. Suppose three pair of rollers to revolve near one another, and a thin ribbon to be passed between them—if they all revolve at the same speed, the ribbon will go through unaltered; should, however, the last or third pair revolve faster than the first and middle pair, the ribbon will be pulled out or elongated somewhere between the first and third. This is the arrangement of the drawing-frame. In practice, the rollers revolve all at different speeds—the third faster than the second. This is the arrangement of the rollers in the finisher carding-engine. The drawing-frame, in which the process is more specially carried out, consists of a series of rollers, *aa*, *bb*, *cc*, fig. 14, the upper of which are covered with leather, and the lower fluted. A flat board, *d*, faced with flannel, presses on the upper rollers, by which they are cleared of all loose fibres. A number of slivers from cans, generally eight, are united into one, and passing over a grooved brass plate, are taken up by the rollers, and finally delivered to a can from between the rollers, *e*. The process not only parallelises the fibres, but tends to equalise the quality of the cotton, making the slivers of uniform strength and texture, by combining many slivers into one. This, which is called 'doubling,' is repeated until all defects are got rid of, and a uniform sliver obtained. Thus, in the first instance, eight slivers are passed through one set of rollers, increasing the chance of uniformity eight times—if four of these are again made into one, the chances are increased thirty-two times, and so on, till the last sliver may contain parts of 300 slivers. The process, however, for fine spinning is carried to a much higher rate of multiplication than this, sometimes exceeding 60,000 times. The distance between the rollers is regulated by the length of the staple. As all the cans sent from the drawing-frame must have the same length of sliver in each, should any of the slivers break, it is of importance that the machine should be stopped at once. This is effected by the machine itself, by the 'patent-stop motion.' The sliver passes to the rollers over a nicely balanced lever, which is kept in position by the friction of the passing sliver; when it breaks, the lever falls out of position, releases a lever which acts upon another lever, and passes the driving-belt from the fast to the loose pulley, and stops the machine. The drawing-frame is of considerable length, containing several sets of drawing-rollers.

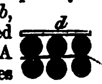


Fig. 14.

The machine next used is called the roving, or slubbing, or bobbin and fly frame; the duty of which is to give the loose, porous, thick cord from the drawing-frame a certain amount of twist, to enable it to be wound upon large bobbins. A series of spindles, *b*, *b*, fig. 15, are made to rotate with great rapidity vertically; these pass through a board, *d*, upon which rest a series of bobbins, *a*, up the central tube of which the spindles pass. The bobbins are made to rotate independently of the spindles, and at a different speed. To the top of the spindle, a fork is attached, the ends of which are bent downwards, so as to be on each side of the spindle like the letter

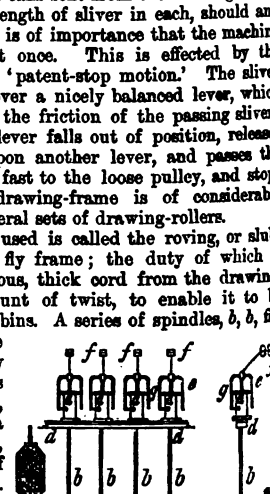


Fig. 15.

U reversed, as *eg*. One arm, *g*, of this fork is hollow, and has at its lower extremity a delivering or spring finger. The sliver is passed from the drawing-rollers, *f*, attached to the frame down the hollow tube, *g*, of the fork, *eg*, and passed round the bobbin, *a*; the machine is now ready for operation, which may be described as follows:—The degree of twist and winding in is entirely due to the difference of speed between the spindle and its attached fork, and the bobbin rotating on the spindle. The revolutions of the fork give the twist, the difference of speed between the bobbin, and the spindle gives the quantity wound on the former. If the finger always remained at the same height, the cotton would be wound up at one place of the bobbin only; to distribute it equally over its surface, the frame on which the bobbins rest moves up and down. As the diameter of the bobbin increases, it is necessary, in order to lay the roving equally on, to decrease the speed—the decrease of speed being proportioned to the increase of diameter. This is effected by having a conical drum, the belt of which works the drum giving motion to the bobbins; as the belt passes from the small end of the conical drum to the large, its velocity decreases. The speed of the spindle and of the delivering-rollers being always equal, the quantity of roving delivered to the bobbins is always uniform; hence, as the bobbin surface increases in diameter, its velocity must be decreased, to enable the same quantity as before to be laid on during the same time. In place of winding the yarn round bobbins, as at *a*, *a*, it is sometimes wound round cylindrical spindles without ends, and made to assume the form shewn at A, fig. 15.

The bobbins, when full of roving laid uniformly on, are taken off the spindles by removing the fork, and put into skips, made of buffalo-hide, wicker-work, or gutta-percha, and conveyed to the next process.

The rovings thus produced are spun into hard, well-twisted yarn by two machines, the throstle and the mule; the former generally spins the harder kinds for the warp, and the latter the softer for the weft of woven goods. In the throstle, the arrangements are very similar to the roving-frame, with this exception, that the bobbins have no independent motion given to them by special means, the difference between the speed of the bobbins and the flyers or forks being caused by the friction of the bottom of the bobbins revolving in contact with a board faced with flannel; this board is called the copping-rail, and moves up and down, to distribute the yarn equally over the surface of the bobbins. The yarn drags the bobbin after it, but the weight of this and its friction on the rail keep it back, thus giving the twist by the difference of the speed.

In the mule, the yarn is not wound upon bobbins, but round steel spindles, and is built in such a way as to be thickest near the middle, gradually decreasing in diameter towards top and bottom; the bottom part, however, being much shorter than the upper, as shewn at *klm*, fig. 16. The mule consists of two essential

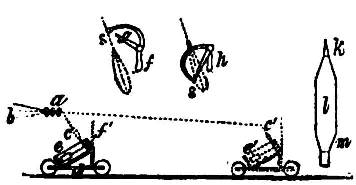


Fig. 16.

parts, one of which is fixed, and contains a row of bobbins from the fly-frame, ranged on a series of spindles, allowing them to rotate as the yarn is drawn from them. On the fixed head, the sets of drawing-rollers, *a*, are fixed. The other part of the mule is the carriage, *d*, which moves to and from the fixed head on parallel rails. The carriage carries a range of spindles, *c*, sometimes 1000 to 1200 in number. On these the yarn is laid to form cops, as they are termed. The spindles are made to revolve rapidly by bands passing from drums, *e*, round pulleys, or 'wharves,' fixed at the lower extremities of the spindles.

To the carriage standards are fixed, carrying a horizontal shaft parallel to the line of the spindles. This shaft is provided at intervals with curved arms, *g*, *h*, fig. 16; these supporting a slender wire, as *s*, *s*. The shaft to which the arms are attached is movable, so that the arms can be brought from the position at *g* into that shewn at *h*. The operation of the machine is as follows:—The carriage is brought up to the 'head;' the drawing-rollers, *a*, give out the yarn, which is wound round the points of the spindles, *c*, the faller-wire, *gs*, being in the position shewn at *sgf*; the carriage then moves outwards at a rate quicker than the yarn is delivered by the rollers, so as to stretch and equalise it; the drawing-rollers, when the carriage has gone out to some fifty or sixty inches, or a 'stretch,' as it is termed, cease revolving, so as to hold the yarn firmly. The motion of the carriage is greatly reduced in speed, while that of the spindles is accelerated; by this means the required twist is given to the yarn. On the carriage leaving the head, any yarns which may have broken are pieced or mended by little children, called piecers. The carriage is now disengaged from the mechanism which moved it on the rails, and the spinner begins his work. This consists of three operations, all of which must be done simultaneously, and with great nicety, to proportion all the movements to one another, on which the fineness and value of the yarn depend. These operations are—the pushing in of the carriage with his knee towards the head stock, or roller beam; placing the faller-wire in the position shewn at *hsf*, fig. 16, so as to bring all the threads to the level of the bottom of the cop; and, lastly, to turn a wheel, by which motion is given to the spindles, at a speed proportionate to the movement of the carriage. Previous to performing these operations, he causes the spindles to revolve in the wrong direction, so as to throw the yarn off the points of the spindles, which was delivered to them during the stretch last completed. On approaching the head, the attendant brings the faller-wire gradually up to the position shewn at *gsf*, fig. 16, thus preparing for another stretch. The carriage mechanism is then put in gear with the main driving-shaft, and the operations above described are again gone through. Thus, by a succession of operations, the yarn is finally built up into cops, which, when finished, are stripped from the spindles, and put into baskets. In the self-acting mule, all the operations are done by machinery, and the only attendance required is that of piecers and menders, the latter being adults. The following illustration shews a range of mules at work.

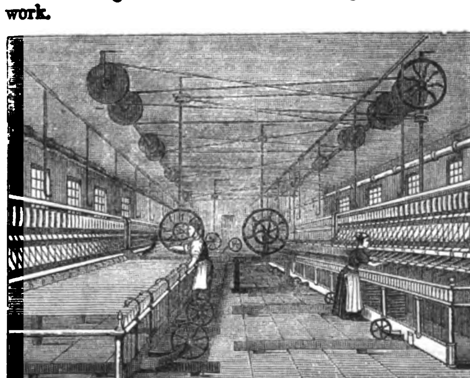


Fig. 17.

To be ready for weaving purposes, the yarn from the

bobbins or the cops is placed upon larger bobbins by the winding-machine, in which the small bobbins from the throstle, or cops from the mule, are placed either vertically or horizontally. The threads from these pass through glass 'eyes' or hooks, fixed to a guide-bar, which has a lateral to and fro movement given to it; and are thus evenly wound upon the surface of the large bobbins. These are taken and placed horizontally on axes placed in the frame, *d*, of the warping-mill, fig. 18. The threads or yarn from a number of these are passed through glass eyes, in a heck-box, *e*; which is suspended by a cord passing over a pulley, the termination of which is wound round the main axis of the upright skeleton framework, *aa*. As the latter revolves, the cord is wound round the axis, and gradually raises the heck-box upwards. On the framework revolving in the contrary direction, the cord is unwound, and the heck-box descends. By this arrangement the yarns are wound spirally round the frame, the circumference of which is so designed that it serves as a measure of the quantity wound upon it. Motion is given to *aa*, by the crank *c*, and pulley *b*. The heck divides the yarn into two sets, one for each heald of the loom.

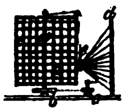


Fig. 18.

The sets, or the 'lease,' of yarn are taken off the frame and wound up in a ball, and taken to the beaming process. The yarn in this is laid on cylinders or beams, and each thread distributed equally, by passing through between shreds of cane fixed in frames. The warp thus formed, is next dressed in the dressing-machine, by which each thread or yarn has a portion of flour-size well rubbed in by brushes and rollers into its fibres. When dried, the warp is stiff, and easily drawn through the healds of the loom, for which it is now prepared. The supply of yarn in the shuttle is always derived from a cop, so that yarn for a weft is never made in the throstle, but always in the mule. We shall, under the head of Wool, describe the movements of the ordinary loom, so that it is unnecessary here to advert to the movements of the *power-loom*, which are exactly similar, but produced by steam-power instead of manual labour. In the annexed engraving is presented a view of the interior of a power-loom apartment. All the looms are of iron, and moved by belts from shafts, the shafts being turned by steam or water power.

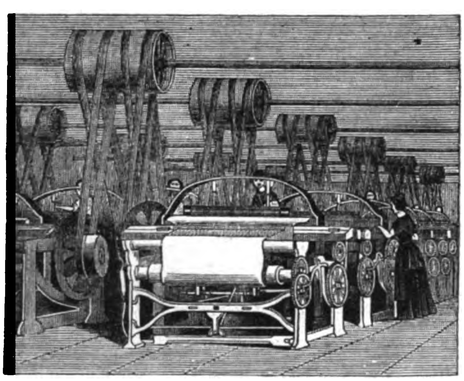


Fig. 19.

SILK.

This beautiful and unrivalled material is the produce of a plain-looking, greedy, leaf-devouring larva—the caterpillar of the silk-moth, or *Bombyx mori*. It is thus directly of animal, though indirectly of vegetable origin; the glutinous caoutchouc principle of the leaves furnishing the worm with the basis of its silken fabric. The silk-worm is supposed to have been indigenous to China; at least the discovery was there first made that the product of this little creature's operations could be elaborated into articles of human attire, richer and more beautiful than any to be derived from other sources. At an early period, a considerable commerce was established in silk between Eastern and Western Asia, from which latter quarter it was conveyed to Europe; but not until the sixth century of the Christian era was it distinctly known by Europeans that the splendid tissues which they had worn for more than a thousand years, and which they had even partially manufactured from the raw transported material, were the product originally of a caterpillar. The first silk-worms seen in Europe were brought from China in the year 552, by two Persian monks, who had gone thither as Christian missionaries, and who contrived to secrete a number of the eggs in a cane, and to escape with them to Constantinople. From these few eggs have sprung all the successive generations of the insect which have supplied silk to Europe from that period to the present time.

As our paper is confined to notices of the *manufacture* of the various materials, not of the processes by which they are cultivated, as in the case of cotton or flax, or produced, as in silk and wool, we pass over the points connected with the rearing, feeding, and treatment of the worm, prefacing our more practical remarks by a notice only of those a knowledge of which is necessary to the due understanding of the processes of manufacture.

The silk, which is the produce of the silk-worm, is passed through two small holes in its head; the two filaments thus passed out, by a combined movement of the mouth and front legs of the animal, are combined into one, being bound closely together by a gummy liquid. This long filament, extending sometimes to a mile, is spun into the shape of an egg-shaped ball, in the interior of which the worm is enclosed. When its labours cease, we have what is called a silk cocoon, from an inch to an inch and a half in length, and of a pale-yellow or orange colour. The cocoons are next subjected to heat, which kills the worms imprisoned within.

The exterior of the cocoon, being the first part spun by the animal, is of poor quality, and is termed *floss silk*. This floss-silk covering is taken off, and exposes the hard cocoon of one continuous thread of fine silk below. The method by which this thread is taken off is known as *reeling*. The silk differs considerably in quality, and the cultivators sort the cocoons, accordingly, into distinct lots, being guided by the observation of colour and other circumstances. The cocoons being prepared and assorted, the material is ready for being reeled. The great point in reeling is to make the thread of as even a thickness as possible: *perfect equality* is scarcely attainable. An experienced reeler, with the assistance of a girl to turn the wheel, can with ease wind off a pound of silk in a day.

A number of cocoons are placed in a dish of warm water, in order to dissolve the gummy fluid already mentioned, and allow the thread to be taken off. The reeler uses a whisk of fine twigs to take up the loose points, which she passes in sets of about five through the eyes of the machine. These compound filaments, after being made to cross and rub on each other so as to clean their surfaces, are combined first two and two, and finally all together into a single thread, which is wound upon a reel or frame, and formed into hanks and skeins.

Raw silk, preparatory to weaving, must be made to take one of three forms—respectively termed *singles*, *tram*, or *organzine*. *Singles* is merely the raw silk twisted, in order to give more firmness to its texture. All raw silk, for whatever manufacture designed, must undergo this process. *Tram* is formed by twisting together, not very closely, two or more threads of raw silk, and this generally forms the weft, or transverse threads of the web. *Organzine*, which is principally used for warp, is produced by a very elaborate process, of which it would be impossible to convey any correct

idea to the general reader without the aid of a diagram. The principle of the process, however, may be generally stated to be like that of making rope, where the combined strands are twisted in an opposite direction to that given to the separate threads, and this is accomplished by giving a reverse motion to the machinery; whereas singles and trams are twisted only in one direction, similarly to twine, or to the individual strands of which the larger rope is made. Silk thread intended for organzine is in the first process twisted in a left-hand direction.

We now proceed to describe the processes by which silk is prepared for weaving purposes. As the mechanism employed for effecting these processes is very similar in principle to that of the 'cotton' machinery, the reader will do well to consult the illustrations of the latter while perusing the following description. This remark applies also to the section on WOOL.

The first to be noticed is that of *winding*. In this operation, the hanks are stretched on a light hexagonal reel, termed a swift. The silk is led from these to a series of bobbins placed horizontally in a frame, some distance above, and in advance of the reels, one bobbin being allotted to each reel. The threads of silk are wound upon the bobbins, uniformly over the surfaces, by being passed through eyes which are placed on a bar having a lateral movement to and fro. The silk thread thus wound upon a series of bobbins is next cleaned—that is, each thread is made to pass through an aperture which is just of sufficient size to allow it to pass through alone, but which detains all extraneous matter: before passing through the hole, the silk is cleaned from dust by coming in contact with a brush.

The next operation is that of *throwing* or twisting, which is effected by spinning-machines, although, correctly speaking, the process is not one of spinning, which involves the presence of short fibres to be operated upon. The silk bobbins from the previous machine are placed horizontally in a frame in one or two rows, one above the other; at a little distance below these horizontal bobbins are placed a series of vertical ones; these, however, have no motion on their axes, like the horizontal ones, but are stationary. A spindle passes through a central aperture on each of the bobbins, and is made to revolve quickly. At the upper end of the spindle, a small flyer (see Cotton) is fixed. The silk is passed from the horizontal bobbin through the eye of the flyer, and by the rapid rotation of the latter round the vertical bobbin, it is wound upon its surface, receiving at the same time a twist. The amount of twist given to the thread is dependent upon the difference of speed between the flyer and the horizontal bobbin which gives out the silk.

In the manufacture of tram, sewing-silk, and organzine, the next process after spinning is that of *doubling*. The bobbins, equal in number to the threads to be united, are set in a frame, the loose ends of the silk of the bobbins are collected and passed through a loop, and finally wound round a horizontal reel. This is placed in the throwing-machine, and the ends carried through the eye of a flyer, which, by its rapid rotation round a bobbin, winds it upon its surface, giving it at the same time the desired twist. A number of bobbins and flyers are arranged in one machine, and an apparatus attached by which, when a thread breaks, the flyer with which it is connected is stopped.

The organzine, when finished, is transferred to reels instead of bobbins, whence it is made up into skeins, and sorted for sale or use. Previously to this, however, the reels are subjected to a process of steaming for two or three minutes, in order to prevent any 'after-crinkling.' The silk thus thrown is called hard silk, and must be boiled for some hours, with a quantity of soap, in order to discharge the gum, and thereafter well washed in a current of clear water, to discharge the soap, after which the silk appears soft and glossy. Besides these varieties, there is another called *sewings*, which are compound threads of silk, wound, cleaned, doubled, and thrown, with especial reference to their ultimate use for sewing. *Marabout* is a peculiar kind of thrown silk, generally formed of three threads of raw silk; and being white as it comes from the cocoon, it takes the most delicate shades of colour at once without the discharge of its gum.

Silk is woven into various fabrics, plain silk being produced by the ordinary loom, and figured by the Jacquard-loom. The fine soft pile of *velvet* is produced during the process of weaving, by inserting short pieces of thread doubled under the shoot or weft, and which stand upright in such a way, and so close together, as entirely to conceal the interlacings of the warp and shoot. In the production of every yard of velvet, six yards of pile at least are used. The loops of the doubled threads intended for the pile are supported by grooved wires, and the loops are afterwards divided by running a sharp instrument, called a *treval*, along the groove. This is done by the hand, and of course requires great dexterity, as the slightest deviation from the proper line would infallibly injure, if not wholly destroy, the silk. It is considered a good day's work for one man to weave one yard of plain velvet, for which he is paid about five times as much as for weaving plain silks.

The refuse of the throwing, and the silk known as floss, are spun by a series of processes analogous to those of the cotton manufacture into yarn, which is used for the manufacture of the cheaper kinds of silken materials. The first process in the *spinning* of silk, properly so called, is the disentangling of the short fibres by a species of hackling, and thereafter parallelising them by a machine called the filling-engine. Next passed through the drawing-engine, the silk is freed from all impurities and extraneous matter by being combed. Cut into short lengths, the silk is then scutched, by which it is converted into a species of fine down. The gum is at this stage removed from it by boiling it in water, and thereafter cleaning it in pure water. Subjected to strong pressure, and dried, it is again scutched, and finally converted into yarn by operations closely resembling those of the cotton manufacture.

In Britain, the annual value of the silk manufacture is estimated at nearly ten millions sterling—more than nine-tenths of which are for home consumption. We draw our chief supplies of the raw material from Bengal; from Italy, which produces about eleven million pounds annually; from China, where, next to tea, it is the staple article of export; from Turkey; and in smaller quantities from Holland, the United States, and other countries. The foreign states in which the manufacture chiefly exists are China, India, Italy, Switzerland, and France. It has been estimated that a million and a half of human beings derive their sole support from the culture and manufacture of silk, and that it creates an annual circulating medium of between thirty and forty millions sterling!

In 1850, the number of silk-factories in England and Scotland (Ireland possessing none) was 277, using 2858 horse-power in steam, and in water 853; the number of spindles was 1,225,560, and of power-looms 6092; and the number of hands employed, 29,877 females, and 12,667 males.

WOOLLEN.

Wool, according to the definition given by Professor Owen, 'is a peculiar modification of hair, characterised by fine transverse or oblique lines from 2000 to 4000 in the extent of an inch, indicative of a minutely imbricated scaly surface when viewed under the microscope, on which and on its curved or twisted form depends its remarkable felting property, and its consequent value in manufactures.' Wool, although principally derived from the sheep in its many varieties, is obtainable also from the goat and other animals. The Tibet goat

furnishes the finest of all wool, the merino sheep the next best.

Wool, as used in our manufactures, is divided into two sorts—the long, or combing, and the short, or carding wool. These, again, give rise to the two grand divisions of the trade—the cloth, or the short-wool, and the worsted, or long-wool departments. It is our duty to explain briefly the various processes gone through in these, taking the cloth as first in order.

On arrival at the factory, the various qualities of wool are sorted, three classes—*primes*, *seconds*, and *thirds*—being the gradations generally used. To free the wool from the animal grease, and enable it to take on the dye, it is *scoured*. The dyeing either takes place at this stage or is deferred till the cloth is woven: when the latter is the case, it is termed *piece*, when the former, *wool* dyed.

The wool is now subjected to the action of the *willy*—much resembling in arrangement and operation the machine of like name in the cotton manufacture. The wool is opened up and projected from the machine in a loose open condition. It is afterwards picked, to free it from all burrs and extraneous matter, and to separate the locks which differ in colour. A machine has been recently introduced, named the burring-machine, which effectually frees the wool from all burrs, &c. Previous to passing through this machine, the wool is well oiled, to render its working more easy. If the burring-machine is not used, the wool, after being picked by hand, is oiled, and passed through the willy a second time. After this is done, it is passed to the scribbling-machine, which is very similar to the breaker carding-engine used for cotton. In the carding-engine, the next machine in sequence, the card-teeth are placed in the main cylinder in the form of narrow strips. The wool is thus passed from the machine in the form of long narrow bands. Each band, as it issues from the machine, passes between a fluted roller and a semicircular case which embraces it; by which means it is rubbed round into the shape of hollow tubes, equal in length to the breadth of the band of wool from which they are cut. The tubes of wool, termed cardings, are next passed to the 'slubbing billy,' the operation of which is similar to that of the cotton roving-machine. The rolls, or tubes of wool, are placed lengthways on a sloping board in front of the machine, and are taken up by the drawing-rollers. The tubes of wool being all of a determinate length, it is necessary to add new lengths to the ends of those passing through the rollers, in order to maintain the continuity of the sliver of wool. To maintain the supply is the duty of the little attendants called 'pieceners.' The wool is finally wound upon the bobbins or spindles, ready for the mule, where it is spun into yarn for weaving. The three preliminary processes are thus seen to be scribbling, carding, and slubbing. By means of a machine known as Mason's (of Rochdale) condenser, introduced a few years ago, and now being rapidly extended in use, a vast deal of labour is saved in the way of 'piecening,' and the three operations of feeding, piecing, and slubbing are effected by one machine. Its operation may be briefly described as follows:—The sheets of wool from the scribbling-engine are wound round rollers; the web of wool thus obtained is laid on the feed-cloth of the condenser, and supplied continuously to a revolving tube, which imparts to it a certain degree of false twist; passing through another tube, it is wound upon a drum, making a continuous sliver, sixteen inches diameter, and four or five inches wide. A number of these narrow laps are placed side by side on rods in front of the machine; the laps from each are passed to the carding-engine, which delivers the wool at the other side in the form of endless bands, which are removed from the main carding-cylinder by doffers. From these the wool is taken by stripping-rollers, and made to pass between double endless twisting straps, which impart to the slivers an amount of false twist. They are finally delivered to bobbins, which are then ready to supply a continuous sliver to the spinning-mule—a machine very similar to the cotton-mule.

The yarn prepared by the mule is then woven into cloth, and ready to be put through the succeeding operations, as follows:—The oily matter is removed from the cloth by scouring, in order to restore the roughness to the fibres, preparatory to the subsequent process of milling. In articles made of long wool, the texture is complete when the stuff issues from the loom. The pieces are subsequently dyed, and a gloss is communicated to them by passing them between heated metallic surfaces. But in cloths made of short wool, which is generally dyed before being spun, the weaving cannot be said to complete the texture. When the web is taken from the loom, it is too loose and open, and consequently requires to undergo another operation, called *fulling* or *milling*. This is performed by a fulling-mill, in which the cloth, being first freed from its oil by the use of fuller's-earth and other detergents, is immersed in water, and subjected to repeated compressions by the action of large beaters, formed of wood, which repeatedly change the position of the cloth, and cause the fibres to felt, and combine more closely together. By this process, the cloth is reduced in its dimensions, and the beauty and stability of the texture materially improved.

The process of milling is now rendered much more speedy and economical by the use of the fulling-machine, which does the same amount of work at a less expense of detergent material. In this machine, the cloth is fastened together so as to form an endless rope, as it were, and subjected to the action of weighted rollers, which press it against the sides of the trough or case in which they work; soap is passed to the cloth through doors made in the machine for this purpose.

This tendency to become thickened by fulling, is peculiar to wool and hair, and does not exist in the fibres of cotton or flax. It depends on the fibres or hairs being barbed or serrated, so as to admit of motion in one direction, but not in another. There thus results an entanglement of the fibres, which serves to shorten and thicken the woven fabric.

The nap, or downy surface of broadcloths, is raised by a process which, while it improves the appearance, tends somewhat to diminish the strength of the texture. It is produced by carding the cloth with the barbed or hooked fruit-cone of the common teasel (*Dipsacus fullonum*), which is cultivated in England for the purpose. This operation extricates a portion of the wool, and lays it in a parallel direction on the right surface of the fabric. Teaseling was at one time performed by hand, a number of the heads being placed in a small frame; machinery is now employed, the teasels being arranged on a revolving cylinder, with which the cloth is made to pass in contact in a direction contrary to that of its revolution. The nap thus formed is then cut off to an even surface by the process of *shearing*. This is performed in various ways; but in one of the most common methods, a large spiral blade revolves rapidly in contact with another blade, while the cloth is stretched over a bed or support, just near enough for the projecting filaments to be cut off at a uniform length, while the main texture remains uninjured.

The cloth is finally prepared for market by a series of finishing processes, as hot-pressing, boiling, and steaming. In the former, the cloth is subjected to enormous pressure between hot plates. Boiling consists of immersing the cloth, tightly wound upon a roller, in warm water, after which it is dried in a hot room while tightly stretched out. In steaming, the cloth is wound upon perforated rollers, into which steam is admitted. After all this, it is closely examined, to take out all unevennesses, and to make up any minute holes in the fabric;

and, finally, it is cold-pressed, and made up into bales, when it is ready for the market.

The second branch of the woollen trade is the worsted or long-wool manufacture. The principal operations in this department being analogous to those of the cotton manufacture, a very brief glance at their nature and sequence is all that is necessary.

The wool is first washed and cleansed, much of the moisture being pressed out after this operation by passing it between rollers. The wool is next dried, and afterwards passed through a species of willow, which opens, cleanses, and straightens the fibres, which are now ready for combing. This is a very unhealthy and tedious process, being carried on in hot rooms. The process consists in placing wool fibres on a comb, evenly laid and firmly fixed between the teeth, and passing the teeth of a second comb through the mass. The teeth of the combs are heated in a stove, so as to render the wool soft and pliant. Each comb has three rows of teeth of different heights: a portion of the wool is left, called noyl, which the comb will not straighten; this is used for coarse yarn. Machines have been introduced to supersede this process, but with indifferent success.

In place of combing, the wool is sometimes straightened and the fibres parallelised by the use of the carding-engine. The slivers of wool, prepared either by combing or carding, are drawn and spun into yarn by machines closely resembling those used for similar purposes in the cotton-trade.

The classification of worsted stuffs is as follows:—1. Fabrics composed entirely of wool; 2. Of wool and cotton; 3. Wool and silk; 4. Wool, silk, and cotton; 5. Of alpaca and mohair, mixed with cotton or silk. 'The first of these divisions comprises the well-known fabrics called merinoes double twilled, so denominated from the Spanish wool of which they were first manufactured. (Bradford produces goods of this class little inferior to the French merinoes.) In single-twilled merinoes, the worsted manufactures of Yorkshire have at all times had the decided precedence. Shalloons, says, serges, lustrings—all stout and heavy articles—are manufactured chiefly at Halifax and Keighley. Damasks for curtains and hangings are also made at Halifax, and this branch of the trade has arrived at great perfection, both in excellence of material and elegance of design. Of the fabrics composed of wool and cotton, the articles denominated Cobourg and Orleans cloth—the former being twilled, and the latter plain—have been staple manufactures, of which the consumption has been immense; they are made chiefly at Bradford and Keighley. Many of the silk-warp and worsted-weft fabrics are distinguished by their richness and durability. The alpaca and mohair manufactures—carried on at Bradford and Bingley—are remarkable for their softness and brilliancy, and the great variety of purposes to which they are applicable. The importation of alpaca wool has increased from 7000 bales in 1836, to 20,000 in 1850; and of mohair, from 5621 bales in 1841, to 12,884 bales in 1850. It is in the production of articles in which wool of various kinds is combined with cotton and silk, that the superiority of the British manufacturer is most apparent, no such goods being produced on the continent to any extent or of any great excellence. The consumption of these various manufactures is immense; the looms are capable of producing upwards of 80,000 pieces per week, averaging thirty yards each.'—(Jury Report of Great Exhibition, 1851.)

Woollen fabrics, manufactured as above, are generally known by the name of *cloths*, of which there are several varieties in common use, as broad, narrow, and habit cloths, all of which are worked plain, and only differ in width or in quality. When twilled, they are termed *kerseymeres*, *kerseymerettes*, *pelisse-cloths*, &c.; and when peculiarly finished—as, for example, with long, tufted, or velvet naps—they are known by such designations as *dreadnought*, *frieze*, *swanskin*, *plush*, and *duffel*. *Tweed* is a light structure, now largely used for trousering; *flannels*, of whatever variety, are all loosely woven; *baize* is a kind of flannel with a tufted nap; and *blankets*, of which there are many varieties manufactured in different parts of the country, are also loosely woven and finished with a long nap raised by rollers covered with brass pins. Besides the manufacture of cloths, blankets, and flannels, the department of woollen fabrics comprehends *carpets* and *hosiery*, two very distinct but important branches. Three kinds of carpets are usually made—Venetian, Kidderminster, and Brussels. Venetian carpeting is a plain fabric, composed of thick linen woof on a woollen warp, and is employed chiefly for stair or lobby coverings. The Kidderminster carpeting is by far the most common; it consists of two woollen webs, woven together, and intersecting each other at particular parts, so as to produce definite figures of different colours. The manufacture of this species of carpets has been long carried on with advantage in different parts of Scotland. Brussels carpets possess a basis of strong linen threads, on which the pattern in woollen is thrown up in loops, which are kept firm by small rods. When the web is woven, the rods are pulled out, leaving a soft surface of the closed ends of loops. Latterly, a great improvement has been made in Brussels carpet-weaving, which has also been adopted for shawls. Instead of using threads of one particular colour throughout, and throwing up the threads as they were required to form the pattern, the custom is now to dye different parts of the same thread with different colours, suitable to the pattern required. Thus a single thread may be dyed in patches of red, yellow, black, or any other colour, and it performs its part in the pattern through its entire length; the saving of material by this ingenious mode of dyeing is immense.

In 1850, the number of factories engaged in the *woollen* manufacture in the United Kingdom was 1497—of which England had 1306, Ireland 9, and Scotland 182. The number of horse-power in steam in the 1497 factories was 13,455, in water, 8769—giving motion to 1,595,278 spindles and 9439 looms.

The number of factories in the same year in the United Kingdom employed in the *worsted* manufactures was 501—of which England had 493, Ireland 2, and Scotland 6. The amount of horse-power in steam was 9890, in water, 1525—giving motion to 875,830 spindles and 32,617 power-looms. The hands employed were 27,337 males and 53,877 females.

Of the process of *weaving* by hand—an operation common to all the textile manufactures we have been describing—we now propose to give a brief description. A certain number of threads arranged alongside of, and parallel to each other, constitute the *warp*. This is evenly wound on the beam, *a*, fig. 20, of a loom, and is thence extended to another beam, *b*, at the opposite end.

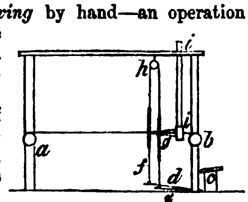


Fig. 20.

Between the beams are suspended two 'healds,' or 'heddles,' seen edgewise at *f*, *g*, fig. 20. A front view of one is presented in fig. 21, where *g*, *h* are two bars, between which cords are stretched, each having a loop, *f*, in the middle. The threads of the warp are drawn through these loops, a thread passing through a loop in each heald alternately. The healds are united by a cord which passes over a pulley, *h*, fig. 20. The bottom bars of the healds, *f*, *g*, are connected to 'treddles,' *d*, *e*; by pressing an end of which alternately, the weaver sitting on *c* can raise and depress *f* and *g*. The threads

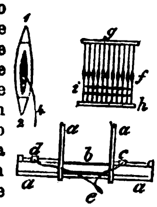


Fig. 21.

of the warp, after passing through the loops of the healds, are taken through the openings or 'dents' of the reed, *b*, fig. 21, attached to the batten or lay, *aa*, which swings to and fro on the frame, as at *ii*, fig. 20. The rising and falling of the healds cause one set of the threads to be raised and the other depressed, so as to cross each other, and make an opening, or 'shed,' as it is termed, from one side of the warp to the other. Every time that the threads are opened, a shuttle, containing the *woof* or *weft*, is thrown across from one side of the warp to the other, and the thread of woof thus left is driven home by a lay, or properly by a comb-like process of reeds called a *dent*, which the lay brings forward. A reversal of the warp makes another opening, which is similarly crossed by the shuttle, and so on, each cast of the shuttle adding to the woven fabric by the breadth of a thread. Plain cloth of all descriptions is formed by this simple species of operation, whether the loom be driven by hand or by steam power.

The shuttle is formed of hard wood, and shaped like a canoe; it is hollowed out in the middle, to afford space for the cop to lie in; the thread of which is brought through a hole in the side. Small wheels are sometimes provided to the shuttle, to enable it to run easily in the 'race.' The shuttle is driven through by what is called a 'fly' and 'picker.' Two pieces of wood, *c*, *d*, fig. 21, known by the latter name, move along a wire, and are connected by a cord, to which a handle, *e*, is attached; by jerking this from side to side, the pickers send through the shuttle with great force.

The only changes of pattern which can be readily produced by plain weaving are stripes or checks—the former generally depending upon the colours of the warp, and the latter upon the colours of both warp and weft. Thus stripes in the direction of the cloth may be produced by using warp of various colours, or a warp composed of threads of different sizes and substances; stripes across the web may be formed by using shuttles containing various colours and substances; checkered patterns, by varying both warp and weft; and figures, to a certain extent, by raising and depressing alternately certain portions of the warp. *Twills* are formed by causing the thread of the weft to pass alternately over four and one of the threads of the warp, and performing the reverse in its return. Plain twilling is adopted in various linen fabrics—in silk, it is called satin; in cotton, fustian or jean; and in woollen, serge or kerseymere. In ornamental or *figure* weaving, an expensive, or at least complex, harness is required, the warp being of various depths, several sets of heddles being also in requisition, and it may be a number of shuttles, each having its own system of thread or threads. It is easy to see how, by these means, a great variety of figures may be produced; and in order that the weaver may clearly understand the intended texture of his piece, all the threads are drawn on cards before he begins, in a manner peculiar to themselves; and these he reads as he proceeds, just as a musician plays from his sheet of music. Looms of this kind, whether for linen, silk, cotton, or carpet fabrics, are known as draw-looms, the most perfect of which is that invented by M. Jacquard, a practical weaver at Lyon. With modifications adapted to the object in view, the Jacquard-loom has now superseded all others for figure-weaving—the skill and labour required to work it being little more than that necessary for plain weaving.

FELT—HATS—STRAW-PLAIT.

Felting is the process by which different kinds of hair, fur, or wool are blended into a compact texture, without undergoing either spinning or weaving. It depends upon the serrated structure of the fibre—a structure which has already been noticed under milling, and which may readily be observed by passing a hair through the fingers in opposite directions. This peculiar structure allows the fibres to glide amongst each other, but only in one direction; so that when the mass is agitated, the root end of each fibre is pushed forward among the rest, but cannot be retracted, which serves to entangle and contract the whole together. Vegetable fibre, being of a smooth linear texture throughout, cannot be felted; and among animal fibres, those are best adapted for the process which are naturally curled or wavy, and have the deepest serratures. Felting is best seen in the making of beaver or stuff hats, to which we shall shortly advert.

The materials commonly used for hat-making are the furs of the beaver, seal, hare, and rabbit, and the wool of the sheep. The furs of most animals are mixed with a longer kind of hair, from which they have first to be separated; they are then cut off with a knife, and sorted by a blowing-machine, which carries the lightest and finest fibres to the extremity of a hollow trunk or funnel, while the heavier and coarser are left at proportionate distances from the fanners, or source of the current. The materials to be felted are next intimately mixed by the operation of *bowing*, which depends on the vibrations of an elastic string; the rapid alternations of its motion being peculiarly well adapted to remove all irregular knots and adhesions among the fibres, and to dispose them in a very light and uniform arrangement. This texture, when pressed under cloths and leather, readily unites into a mass of some firmness. A piece sufficient to form a hat is next taken up, and dipped in warm water, containing a little sulphuric acid, and moulded into a large conical shape, which is afterwards reduced in its dimensions by working it several hours with the hand, for the purpose of further thickening and fulling it. At this stage any knots are removed, and fresh felt here and there added; the hat is then shaped, water-proofed by a lac varnish, tied upon a block, dyed, stiffened by the application of a solution of glue, steamed, brushed, and ironed. The brim is then trimmed, and it is ready for lining and binding. The material felted as above described generally consists of a variety of furs, as those of the hare, rabbit, and beaver, lamb's-wool, goat and camel's hair, cotton, and silk. Most manufacturers make what they term a foundation of coarser material, to which they apply beaver or other fine furs as a *plate* or finish. What are called *beaver* hats are thus completed with the fur of that animal; while in *stuff* hats this fur is altogether omitted. *Silk* hats have a foundation of felt, chip, straw-plait, whalebone, or pasteboard, upon which silk-plush is afterwards applied. From their cheapness, durability of colour, and lustre, they have lately come much into use, though scarcely so durable, or so soft and elastic for the head, as the old beaver. The best variety of the silk hat is that in which a fine Paris plush is fixed upon a beaver body. *Gossamer* hats, for summer wear, are those in which the foundation or body is of willow-chip or other light material, with a plush of floss-silk.

Felt cloth, manufactured much in the same manner as felt for hats, is a fabric employed for several economical purposes. At one time, it excited considerable expectation as a substitute for woven woollen-cloths, and perfect imitations of these were produced, but they were found deficient in firmness and durability. More recently, a pneumatic process of felting was introduced, of which better hopes are entertained. The mode is as follows:—Into an air-tight chamber is put a quantity of flocculent particles of wool, which, by a kind of winnowing wheel, are kept floating equally; on one side of the chamber is a net-work, or gauze of metal, communicating with another chamber, from which the air can be abstracted by an exhausting syringe or air-pump; and on the communications between the chambers being opened, the air rushes with great force to supply the partial vacuum in the exhausted chamber, carrying the flocculent particles against the netting, and so interlacing the fibres, that a cloth of beautiful fabric

and close texture is instantaneously made. The only objection to cloth of this kind was its rawness, or liability to shrink after being wetted; and for this reason, we believe, it has never come into anything like use for clothing. Coarse feltings, variously treated, are used for roofing, underlaying copper-sheathing, and other analogous purposes; and for these ends their cheapness renders them specially available; but where elegance and durability are sought to be combined, as in dress and household furnishings, woven fabrics must ever take the precedence.

Straw, plaited, or otherwise worked into a fabric, is in use in almost every country as a material for a light and ornamental head-dress. Many of the tropical grasses are eminently fitted for this species of manufacture, and thus navigators often bring from the Indian Archipelago and South-sea Islands hats, fans, baskets, and other articles, exhibiting a beauty of texture and intricacy of design which the most expert straw-plaiter in Europe could scarcely surpass. It is to straw-plaiting as a branch of civilised industry, however, that we would now direct attention; and for this purpose present the following abridged exposition from the *Encyclopædia of Domestic Economy*:—*Dunstable* hats are made of whole straw, plaited in long narrow stripes or ribbons, which are afterwards sewed together in the form of a hat or bonnet. The weight and clumsy appearance of these bonnets first suggested the idea of splitting the straw into stripes; but it was a considerable time before a method was invented of performing this in a perfect manner. *Split-straw* is an elegant manufacture, brought into use about forty years ago, and has now become very general for women's bonnets. The straw of wheat or of rye is cut at the joints; and the outer skin being removed, it is sorted into small bundles, and is next split by means of a very simple instrument, and delivered to be plaited. The plait is sold by the score yards, and about three score and a half will make an ordinary-sized bonnet. It is sewed by the bonnet-makers, and then blocked, which is a laborious process; and after being pressed, wired, and lined, is ready for sale. There are markets in the plait districts for the sale of straw, plait, and bonnets; the best market for the latter is St Alban's. Straw is bleached, and straw-hats cleaned, by putting them into a cask into which a few brimstone matches are placed lighted. The fumes of the sulphur have the effect of destroying the colour and whitening the straw. The same effect may be produced by dipping the straw into chloride of lime (common bleaching-powder), dissolved in water, an article which may now be procured at any large chemist's. Of straw-hats, the *Leghorn* are the most highly prized, as the finest in the world; they are made in the neighbourhood of Florence, Pisa, the district of Siena, and the upper part of the vale of the Arno, and are exported from Leghorn. The straw is produced from a small kind of wheat, cultivated on a poor soil, and bleached like flax; it is remarkable for its strength and whiteness; the plait is extremely regular, and the straw is not split. Attempts have been made to grow this kind of wheat in England; but hitherto without success. About twenty years ago a firm established straw-plaiting in the Orkney Isles, and adopted rye-straw as the material. At first, there seemed some prospect of success; but it does not appear that the competition of foreign-grown straw could be successfully met. Various other materials besides straw are used for making light hats. *Chip*, which is thin strips of wood made by a plane, is employed; the *willow* is found to answer well, and these strips are woven with a loom into a kind of twill or diamond tissue, and afterwards bleached like straw.

PAPER.

The earliest kind of paper, or material for writing on, of which we have any account, was the *papyrus*, used by the ancient Egyptians; and hence our modern word *paper*. The papyrus was a plant, from which thin fibrous membranes were stripped, and the membranes being pressed together, formed small sheets of a rude kind. The Chinese are said to have understood the art of making paper from the pulp of rags in very early times; but whether the European mode of making paper was derived from that quarter, is not clearly known. The art was introduced amid the obscurities of the middle ages, and most likely through the ingenuity of the Arabians. In the beginning of the fourteenth century, a paper-mill was established at Nuremberg in Germany; and in 1588, a mill was erected at Dartmouth in England. Little progress was made, however, in the manufacture of paper in this country before 1770, when the first mill for fine paper was established at Maidstone by the celebrated J. Whatman. The previous supply had been derived principally from France and Holland.

The principle on which paper is made is very simple: a portion of linen cloth is ground to pulp; this pulp is shaken in a fine wire-sieve, so as to settle in a thin cake, or sheet; the sheet is pressed, in order to squeeze out the liquid; and when dry, we have a sheet of paper. Instead of new linen cloth, rags, for the sake of economy, are always employed; and the more substantial the rag, the stronger in texture is the paper. The quantity of rags produced in Great Britain and Ireland being altogether insufficient to supply the demand for paper, large importations take place from continental Europe, chiefly Germany. Cotton rags, and the refuse cotton of factories, are also employed in the paper manufacture; but only for inferior sorts, or as an alloy, which is not always justifiable.

Any vegetable fibre, indeed, may be used in the fabrication of paper; and straw is much employed in the manufacture of the commoner kinds. A recent patent proposes to make paper from stone.

The great proportion of paper in use is made by machine, very little indeed being made by the old hand-process; to a description of machine-made paper we shall therefore confine ourselves.

Preparation of the Rags.

After the rags arrive at the mill, they are picked and sorted into four or five qualities. All substances not suited for paper-making, or which might injure the machinery—such as pins, buttons, pieces of silk, and woollen cloth, must be carefully removed. The rags are then cut up into pieces about four inches square, by bringing them up against the standing edge of a fixed knife. After being cut, they are well agitated in a cylinder, which frees them from particles of dust. The rags are then boiled in an alkaline lye composed of from four to ten pounds of the carbonate of soda to the hundredweight of rags, according to their quality, and a third part additional of quicklime, to render it caustic.

After being boiled, the rags are carried to the first washing-engine, which consists of a large oblong stone trough, into which a stream of water is allowed to flow, and to escape by the other end. This cleans the rags most effectually, the run of water carrying away any impurities that may still adhere to them. On one side of this trough is an engine, which again washes and grinds the rags, and is termed by the workmen the *breaking-in machine*. This powerful apparatus consists of an elliptical-shaped trough, made generally of wood, lined with lead or copper; within it, a grooved roller revolves horizontally over the surface of a sharply grooved plate, by which the rags are torn to shreds. The grooves on the roller, and those on the plate, act upon the pieces of rags much in the same manner as cutting with a pair of scissors. The trough is half-filled with water, which comes in at one end, and escapes through holes at another part. The operation of *grinding*, as it is called, occupies about an hour and a half; and when the rags are sufficiently reduced to a pulp, the stuff is passed down from the trough to the draining-boxes. On reaching

the draining-boxes, the water is allowed to run off from the pulp previous to the bleaching-process. The common method of bleaching is to steep the pulp in a solution of chloride of lime, by which the fibres are not so much injured as when chlorine is used. In bleaching, great care should be taken that the solution is not too powerful, or the texture of the paper may be materially injured by the process.

After bleaching, the pulp is again put into a washing-machine, to free it thoroughly from the bleaching-liquor. This process is similar to that previously described, except that the roller is screwed down closer to the fluted plate, so as to reduce the pulp to a finer consistence. In making what is called machine-paper, the size is now added, the addition or the want of which constitutes the chief difference between paper for the reception of ink and the other sorts. The kinds of size principally used consist of either white soap, starch, glue, or dissolved rosin, with the addition of a few pounds of alum. The size is strained through a sieve into the beating-engine, and there mixed with the pulp.

From the second washing or beating machine, the pulp is passed down to a large tun or vat, called the *stuff-chest*, which is merely a reservoir to keep the pulp till it is put into the machine which converts it into paper. This vat is furnished with agitators at the bottom, to keep the pulp of an equal thickness, which now bears a strong resemblance to curdled milk. Previous to its being put into the vat, however, it is now almost universally the practice to strain the pulp through bars of brass. These are planed perfectly smooth at the edges, and placed so closely together, that the fibrous part of the matter must pass through longitudinally. By this means, knots, &c., are kept out, which formerly cost considerable trouble to scrape from the surface of the finished paper. This strainer was the invention of Mr Ibbetson of Poyle, to whose ingenious contrivances the paper manufacture is greatly indebted.

From the vat or stuff-chest, the pulp, prepared as already described, is let out by a sluice into a pipe, which leads it to one end of the *making-machine*. The opening from this corresponds exactly with the breadth of the machine; and the quantity and thickness of the stuff admitted into the latter are regulated according to the kind of paper to be made.

The machine now in general use for the making of paper is the invention of Louis Robert, a Frenchman, and was brought to this country about sixty years ago by a M. Didot, who, with the assistance of M. M. Fourdrinier, and Mr Donkin, the engineer, greatly improved the invention, and obtained a patent for it.

The first part of the machinery upon which the pulp comes is a brass wire-cloth, which is woven in the same way as linen, and is of so fine a texture that there are seventy wires in the inch. This wire-cloth may be described as a sort of belt without any break, which is kept continually revolving, but in such a way that the upper side, upon which the stuff is received, preserves a flat and horizontal surface. The wire-cloth moves upon a number of small copper-rollers, which have an agitating horizontal motion, and this distributes the stuff equally over the cloth, giving a uniform strength and thickness to the paper. After passing between a pair of rollers, where it delivers the stuff, it is led backwards again under the frame; and so goes on in a continuous revolution. Movable sides are attached to the upper surface of the wire, which regulate the breadth of the sheet to be manufactured.

The first pair of rollers through which the stuff passes are called the couching-rollers. The under roller is simply cast iron, while the upper one is covered with woollen cloth of a peculiar texture, manufactured for the purpose. It is upon this upper one that the stuff is delivered. The pressure from these rollers is slight; and the pulp is next led on to an endless felt, and passes between two cast-iron rollers. The machinery of this felt must be so regulated that it will go with the same speed as the wire-cloth and couching-rollers, otherwise confusion would ensue. In passing through the first pair of rollers, only one side of the stuff is rendered smooth; but in the second pair it is reversed, and the rough side is now pressed. These rollers are closer than the first pair, and the pressure being greater, the sheet is now more dry and firm.

The sheet next passes through two other pair of rollers, which press out the water, and render the paper smooth and firm. It is then carried to the drying-cylinders, which are hollow, and filled with steam, introduced by pipes placed at both ends of their axes. The paper is again passed through a pair of rollers, to smooth it after being dried, and is then wound upon a reel. As one reel is filled, it is taken off, and another put on in its place; and it is evident that the paper can be made of any length the reel is large enough to hold.

The whole machinery upon which the process we have described is performed, is about fourteen feet in length, and moves at the rate of from twenty-five to forty feet per minute. At one end is seen running in a stream of liquid resembling curdled milk, and at the other comes out a finished fabric, the time required for manufacturing thirty feet of which is little more than a minute. Near the extremity of the machine is usually placed an apparatus for receiving the reels of paper in web, and drawing out and cutting the web into sheets according to the regulated size. The sheets are then sorted and packed up in the usual manner.

By the operations now described, all the printing-papers, and also letter-papers of an ordinary kind, are now made, and that to an immense extent.

In 1851, there were 413 machines at work in the United Kingdom; and the annual value of the paper manufactured is stated to be two millions sterling.

CAOUTCHOUC—GUTTA-PERCHA.

These two remarkable substances, to which we have briefly adverted in previous numbers, are now so largely used in connection with textile fabrics, that a more extended notice of their properties and applications may not be uninstructive to the reader.

Caoutchouc was first seen in Europe about the middle of the eighteenth century. It was then brought from Guiana, and other provinces on the eastern coast of South America, and, from its valuable power of cleaning paper, was called *India-rubber*. It is the produce of several tropical trees, particularly *Ficus elastica*, *Jatropha elastica*, and *Urceola elastica*. It may also be obtained from the juices of others belonging to the same natural order; but our commercial supplies, which now amount to several hundred tons yearly, are mainly derived from the *Ficus elastica* in the old world, and from the *Jatropha* in the new. The mode of obtaining it is simple:—In the cooler seasons of the year, incisions are made around the tree, completely through the bark, and the milky juice which exudes is either immediately applied to moulds of unburnt clay, or collected in vessels. If applied to moulds, it is dried, layer by layer, over a wood-fire, till of the desired thickness; if otherwise, it is allowed to coagulate and harden at leisure. Caoutchouc in the solid state is highly elastic, is insoluble in any of the ordinary solvents, melts at 248° Fahrenheit, and remains viscid for a considerable time, is highly inflammable, burns with a white flame and much smoke, emitting at the same time a peculiar and offensive odour. When solid, it may be cut into threads and sheets of great tenuity and thinness; when melted, it may be used as a lute or cement; and when dissolved in naphtha, which is the most common solvent, it may be employed as a varnish, and applied to the surface of any textile fabric, rendering it quite impervious to air or moisture. The applications of caoutchouc to useful purposes are very numerous; with many of these our readers are doubtless acquainted; and every year sees acquisitions

to their number. In the short space at our disposal, we can only notice the most remarkable.

The water-proof garments well known by the name of Mackintoshes—from the name of the inventor—are formed of fabrics covered on one side with the caoutchouc; or two fabrics are joined by a thin layer between them. To obtain the material in the thin sheet required, it is dissolved, or rather, under the improved process, it is kneaded with powerful machinery, along with the spirit of turpentine or naphtha, until it is thoroughly softened without being liquefied; it is then spread upon the cloth by means of a flattening mill. The cloth thus made has, however, the peculiar property of becoming stiff and rigid in cold weather. This property of caoutchouc has been taken advantage of in the manufacture of garters and other materials formed of elastic threads. The caoutchouc is cut by ingenious machinery into long bands; these are raised in temperature, stretched out to form long threads of small diameter, and wound upon bobbins. The threads are next covered with silk or cotton, or left uncovered; and are capable of being woven by themselves, or in conjunction with other materials, into water-proof cloth. The difficulties in weaving arising from the ordinary elasticity of the material, are fortunately overcome by reducing the temperature of the threads, and by taking advantage of the property the threads have of eventually accommodating themselves to the stretched-out form. Their elasticity is again restored, after the weaving process is effected, by raising the temperature; this causes the cloth to be reduced in length without being increased in width.

Water-proof elastics thus formed, although very strong when pulled in the direction of the length of their fibres, are very weak when pulled transversely. To obviate this, Mr Goodyear has invented a species of fabric or 'artificial felt,' which, pulled in any direction, is very strong. This felt, covered with India-rubber in a pulpy state, which penetrates the interstices, is rendered still more cohesive, and forms a species of water-proof paper or 'real vegetable parchment,' useful in covering damp walls, &c. By covering a sort of woollen wadding with this, very light and warm water-proof cloth is obtained at a slight cost. Its applications are very numerous.

A species of velvet has been produced by means of caoutchouc, by J. Wansborough of London. It is effected by covering ordinary cotton or woollen cloths with a coating of glutinous caoutchouc, and strewing over this the different coloured wool-powders obtained by the shearing of cloths. This fabric is strong and water-proof, and is highly spoken of. It received a prize-medal in 1851.

By the important process of vulcanising India-rubber, it has its utility greatly increased, and is made to exhibit such properties, that it may be said 'to form a new substance.' The process is thus described:—The caoutchouc is immersed in a bath of fused sulphur, heated to a proper temperature, until, by absorbing a portion of the sulphur, it assumes a carbonised appearance, and eventually acquires the consistency of horn. The same condition can, however, be produced by either kneading the India-rubber with sulphur, and then exposing it to a temperature of 190° Fahrenheit, or by dissolving it in any of the common solvents, as turpentine, holding sulphur in solution or suspension. The *rationale* of this operation appears to be, that the India-rubber forms an actual chemical compound with the sulphur; becomes, in short, a sulphuret of caoutchouc, the properties of which are thus enumerated: The new compound *remains elastic at all temperatures;* vulcanised caoutchouc is not reducible by the ordinary solvents, neither is it affected by heat within a considerable range of temperature. Finally, it acquires extraordinary powers of resisting compression, with a great increase of strength and elasticity. This process was originally discovered by Mr Goodyear in America; but it was independently discovered in England by Mr F. Hancock: thus affording an instance of 'a novel solution of a problem which was known to be solvable, since it had been already solved.' A remarkable application of this material has been made by Mr Hodges, who uses it as door-springs, and as a projectile force.

By combining caoutchouc with sulphur and magnesia, Mr Goodyear has imparted to it the hardness and rigidity of wood, but at the same time a plasticity which enables it to be produced in a variety of forms. The manufacture of over-shoes of India-rubber is a branch of considerable importance, one company making no less than 3000 pair a day. Indeed, the manufacture of caoutchouc in its various forms is a remarkable instance of the rapidity with which special manufactures assume a high commercial importance. Thus, in America, Mr Goodyear has granted numerous licences to companies under his various patents, and has embarked in his manufactures the enormous capital of two millions sterling. It is right to notice, however, that the material enjoys a much more extended use in America than in Great Britain, for what are luxuries in the Old World, are often articles of everyday use in the New, even among the labouring classes.

Gutta-percha is of recent introduction into England, having been first brought under the notice of the Society of Arts by Dr Montgomerie in 1843. The tree from which it is procured is said to belong to the natural order *Sapotaceæ*, and is found abundantly in Singapore, the Malayan Peninsula, Borneo, and in all probability throughout the entire Indian Archipelago.

Gutta-percha comes to us in two forms: in thin slips or scraps, or in rolls, which are formed by rolling the thin layers together in a soft state. When pure, the slips are transparent, and somewhat elastic, varying in colour from a whitish yellow to a pink. In the mass, it is seldom free from impurities—such as saw-dust, pieces of leaves, &c. It is purified by a process called 'devilling,' or kneading, which is done in hot water: the water soon dissolves some of the foreign matters, and washes out others, until, after a short time, the gutta-percha is left in a mass, ductile, soft, and plastic, of a whitish-gray colour. Thus prepared, gutta-percha possesses very curious properties. Below the temperature of 50°, it is as hard as wood, but it will receive an indentation from the finger-nail. It is excessively tough, and only flexible in the condition of thin slips: in the mass, it has a good deal the appearance, and something of the feel, of horn; its texture is somewhat fibrous; and it offers great resistance to anything rubbed across it; a property which suggested what appears to have been its first application—as a substitute, namely, for horn for the handles of knives and choppers. By an increase of heat, it is made more flexible, until, at a temperature considerably below the boiling-point of water, it becomes like so much softened bees-wax. It is now easily cut and divided in any manner by a knife, and may be moulded into all varieties of form with the greatest ease; or it may be cut, and united again so perfectly, as scarcely to exhibit even the appearance of a joint, and possess all the strength of an undivided mass. Whatever be the shape into which the gutta-percha is formed while warm, it will retain precisely as it cools, hardening again to its previous state of rigidity. It is in a great measure devoid of elasticity, offering a striking contrast to caoutchouc, but its tenacity is little less than wonderful: a thin slip, an eighth of an inch thick, sustained a weight of forty-two pounds, and only broke with a strain of fifty-six pounds. It is impossible here to detail the vast variety of uses to which this substance is being put; indeed, time alone can determine the extent to which gutta-percha, and its congener caoutchouc, will be applied in the useful and ornamental arts.

Decorative Design as applied to Textile Manufactures.—In concluding our notice of the *materials* and the modes of *manufacturing* the principal varieties of textile

fabrics, it seems desirable to add a few remarks on those principles which are pretty generally received, regulating the application of ornament to the decoration of their surfaces. In placing these before the reader, we shall follow the order in which we have already discussed the varieties of textile fabrics, commencing with *linen*. Linen damask, as used for table-cloths and napkins, receives its ornament from a peculiar distribution of the threads in the weaving, surface-printing being rarely if ever applied to linen. In the application of ornament to this fabric, the designer should aim at flatness of treatment, avoiding all subjects in which relief is required. This excludes representations of architectural reliefed ornaments, fruit, and, indeed, all subjects perspectively treated. The design for a table-cloth naturally divides itself into two parts—the centre space and the border. In the border, or that portion which falls over the edge of the table, the lines should be flowing, while the centre space may be filled up with a diaper arrangement of geometrical figures, or conventionalised floral or natural forms well distributed.

Cotton.—The ornamentation of cotton fabrics is almost exclusively effected by surface-printing. The two great classes of ornamented cottons are *garment* and *furniture* fabrics. As colour is used very much in these fabrics, the designer must view the ornamentation he is desirous to carry out in a twofold aspect—form and colour.

True symmetry of form can only be obtained by a geometrical distribution. That 'ornament has a geometrical distribution, and is subject to symmetry and a correspondence of parts,' will be easily seen on considering that, in the words of Mr Redgrave, 'it is not possible to cover a large space with a repetition of small ornaments without *some* symmetrical arrangement developing itself.' And wherever the eye has a difficulty in tracing this symmetrical arrangement, it may be at once concluded that the treatment is unsatisfactory; it will, in fact, be wanting in the essential character of 'repose.' From these remarks, it will be inferred that 'dispersed' patterns, as they are called, applied to garment fabrics, are in bad taste—by dispersed being meant an irregular sprawling of the pattern over the surface of the fabric, in contradistinction to that symmetrical arrangement which we have above alluded to. The character of the ornamentation should also be attended to—leaves, sprigs, flowers, and simple scrolls being most suitable, and those of course treated flatly, avoiding all relief and perspective. Small forms will also be in better taste than large. The 'making up' and the 'nature' of the material have also to be observed. The first is very essential; and it is to a complete negation of the peculiarities of the human form that we see such monstrosities in garment fabrics perpetrated as *checks*, in which the pattern is made up by horizontal and vertical lines crossing each other. With reference to the nature of the material, the designer should remember that it has certain peculiarities which should not be lost sight of; that cotton, for instance, has not the surface lustre of silk, and that patterns applicable to the latter will, if applied to the former, display a want of truth. Again, cotton is a material easily cleaned; in fact, its most pleasing peculiarity is this idea of purity it conveys. Unlike wool, therefore, which partakes of opposite qualities, the pattern should be so arranged that a large portion of the surface be left in its natural condition. In deciding upon the form to be used, this point should not be lost sight of, that simplicity is elegance; all designs that are intricate in form, and multifarious in colour, contrast very unfavourably with those in which a simple ornament is judiciously distributed, and treated with a simple arrangement of colour.

The distribution of colour is an important point, and one on which much might be said; space only allows us to notice the received canon, that complete harmony, or perfect composition, is only attainable by a judicious admixture of the three primary colours, yellow, red, and blue.

The following is given by Mr Redgrave as an enumeration of the principles which should regulate the application of design to garment-fabrics. 'The ornament is always flat and without shadow; natural flowers are never used imitatively or perspectively, but are conventionalised by being displayed flat, and according to a symmetrical arrangement; and all other objects, even animals and birds, when used as ornament, are reduced to their simplest flat form. When colour is added, it is usually rendered by the simple local hue, often bordered with a darker shade of the colour, to give it a clearer expression; but the shades of the flower are rarely introduced.' It is worthy of note, that the fabrics in which those principles were applied in the Great Exhibition of 1851, were those exhibited by the East India Company. They shewed 'how much beauty may be obtained by simple means when regulated by just principles; and how perfectly unnecessary are the multiplied tints by which modern designers think to give value to their works, but which increase the difficulties of production out of all proportion to any effect resulting from them; nay, even to the absolute disadvantage of the fabric.'

In the treatment of *furniture fabrics*, many of the suggestions we have already given will be applicable. The prevailing aim has hitherto been to have large decided figures, giving ample scope for the display of gay and striking colours. Hence have originated vulgar gaudy patterns, in which obtrusiveness and want of *design*—using the term in its most significant sense—have been the chief characteristics. The symmetrical arrangement of a simple ornament with flat treatment, as already described, will be found much more pleasing than the absurd patterns too frequently used.

Silk and Woollen Fabrics.—The principles we have already indicated for the decoration of cotton, will be applicable in great measure to these; attention, however, must be paid to the nature of the material. Thus the beautiful peculiarity of silk, its brilliant lustre, must not be hid by any over-colouring or a redundancy of ornament; this, of course, does not refer to self-coloured silk, or to brocades where the ornament is of the same colour as the body of the material. Again, the nature of wool admits of a greater redundancy of ornament, and a larger amount of colour.

The following we give, in conclusion, as the principles applicable to printed garments, sanctioned by the Department of Practical Art. 'The ornament should cover the surface, either by a diaper based on some regular geometrical figure, or growing out of itself by graceful flowing curves.

'The *size of the pattern* should be regulated by the material for which the design is intended—small for close thick fabrics, such as ginghams, &c.; larger for fabrics of more open texture, such as muslins, Bareges, &c.; largely covering the ground on de laines, and more dispersed on cotton or linen goods.'

Carpet Decoration.—The main idea which a carpet should convey is an easy natural surface to walk upon, and not obtrusive—that is, it should look flat, and its colours should be 'subordinate to the more prominent pieces of furniture.' Hence all carpets in which huge flowers or floral subjects, architectural ornaments, and the forms of living objects, are portrayed in high relief and with perspective effect, and which 'challenge attention by the brilliancy of their hues in masses, or the tortuosity of the lines in the boundaries of their forms,' are considered to be in bad taste; and hence, also, the principles which dictate flat forms, without shadow or relief, and well distributed over the whole surface. As regards colour, all violent contrasts should be avoided, and 'graduated shades of the same colour, or a distribution of colours nearly equal in scale of light and dark, should be adopted; secondaries and tertiaries, or neutralised primaries, being used rather than pure tints, and lights introduced merely to give expression to the form.'

MINING—MINERALS.

THE term *Mineral* is somewhat varied and indefinite in its application. In the widest sense, it is made to embrace the whole of inorganic nature; and thus we speak of the mineral in contradistinction to the vegetable and animal kingdoms. Occasionally, it is restricted to those native products which appear in a crystallised or definite form; but more generally and properly it is extended to all the earths, rocks, salts, and ores which are obtained from the crust of the earth. Employing it in the latter signification, we intend, in the present sheet, to treat of the nature, origin, and uses of such substances as coal, limestone, sandstone, rock-salt, sulphur, gems—reserving consideration of the metallic ores and metals for a subsequent number. It is almost superfluous to observe, that the mining, digging, transport, and preparation of these materials for application to the purposes of civilised life, constitute departments of human industry of high scientific, as well as economic importance.

For the more accurate comprehension of the subject, it may be necessary to premise that we speak of the *crust* of the earth—meaning thereby that superficial rind or portion accessible to human investigation—in contradistinction to the interior masses, concerning the nature of which we can only form conjectures. In this crust the rocky substances are variously arranged: some are found in layers or strata—hence said to be *stratified;* others appear in vast irregular masses, presenting no trace of bed or layer, and are accordingly termed *unstratified*. The matter of the stratified has evidently been deposited from water, and from this view of their origin, they are generally known as *aqueous* or *sedimentary* rocks; while the unstratified, presenting no appearance of deposit, but everywhere an irregular configuration, and, moreover, often breaking through and contorting the stratified, are considered of *igneous* or *volcanic* origin. Both sedimentary and igneous rocks present various mineralogical and chemical characters: thus, of the former, we have roofing-slate, sandstone, coal, limestone, &c.; of the latter, granite, basalt, and lava—all very distinct in composition and appearance. Besides differences in mineral composition, the sedimentary rocks contain different kinds of fossils—that is, the petrified remains of animals and plants; and such distinctions have rendered it necessary to arrange the rocks constituting the crust of our globe into various *formations*—meaning by a formation any suite of rocks possessing some peculiar mineral or fossil character. Thus we speak of the 'coal-formation,' meaning thereby not merely the beds or layers of coal, but the sandstones, shales, ironstones, and the like, which alternate with and accompany that mineral—seeing that the whole have been evidently deposited under similar conditions, and that similar organisms are found fossil within them. Further, both the stratified and unstratified rocks are frequently traversed by rents and fissures, some of which are entirely void, others partially filled or lined with crystallised products differing from the adjacent rocks, and many, again, wholly filled up with crystallised substances, metallic ores, and other ingredients, constituting what are termed *lodes* and *veins*. (See GEOLOGY.)

BITUMINOUS SUBSTANCES.

Bitumen—from a Greek word signifying the pitch-tree—may be regarded as embracing all those inflammable minerals which, like pitch, burn with flame and smoke in the open air. Naphtha, petroleum, and asphalt are familiar examples; but all substances impregnated with these bitumens are said to be *bituminous*. Hence under this head may be included coal in all its varieties, as well as bituminous slate, slaggy mineral pitch, and the asphalts of commerce.

Coal.

Coal, of which there are several distinct varieties, is one of the most important minerals with which man has yet become acquainted. It is uncertain when coal first began to be used in Britain as fuel, but in all probability it was not earlier than the beginning of the twelfth century. In 1281, Newcastle is noticed as having some trade in that article; and a little later we find it mentioned in the chartulary of the Abbey of Dunfermline. In the reign of Edward I., its use in London was prohibited, in consequence of the supposed injurious influences of the smoke; and this prohibition we find renewed at several subsequent periods, but all to no purpose. The increasing scarcity of wood as fuel rendered some other substitute necessary; and, from its compact form and powerful heat, no known substance could for one moment be brought into competition with coal. The smoke-nuisance was therefore submitted to; and, despite of every obstacle, the 'obnoxious' mineral was soon in the ascendant. At the beginning of the sixteenth century, it seems to have been getting into use in the Lowlands of Scotland, where we find Boethius taking notice of a 'black stone' found in Fife and the Lothians, the heat of which was sufficiently intense to fuse the most refractory metals. Since the time of Charles I. it has become almost the only description of fuel used in London, and in most other towns and districts throughout the kingdom—peat or turf being but occasionally employed, and that solely in remote localities. It is within the current century, however, that the great demand has been made upon our coal-fields; since the application of the steam-engine to the purposes of the mine, the factory, the railway, and river; since the introduction of gas, the extension of our foundries, and the general advancement of those economical processes which distinguish the present from every other period of our country's history. According to the most recent estimates, not less than forty millions of tons of coal are raised from the different mines in the British Islands, of which between three and four millions are exported to other countries.

The coal worked in Britain may be said to be exclusively obtained from the great coal-formation, where it alternates with strata of sandstone, bituminous shale, bands of ironstone, fire-clay, and impure limestone—the whole suite being usually termed the *coal-measures*. Attempts have been made to work the thin beds found in more recent formations, as the oolite and tertiary, but in every case without much success. The principal districts, or 'fields,' as they are called, are those of Northumberland and Durham, Lancashire, Stafford, South Wales, and the Lowlands of Scotland—the latter extending from Fife to Ayrshire at an average breadth of about thirty miles. In these fields there may be as many as ten, twenty, or even forty seams or strata of coal, varying from a foot to thirty feet in thickness; but of these, in general, not more than five or six can be worked with profit. The mineral so obtained is of different varieties and qualities: so pure, as to leave after combustion the smallest percentage of ash; or so foul, as to be burned with difficulty. The principal varieties are—*caking* coal, a highly bituminous sort, like that of Newcastle, which emits much smoke and gas, and cakes together during combustion; *cubic*, which is also bituminous, but breaks

into larger cubical masses, and does not cake while burning; *splint*, a hard slaty variety, which is still less bituminous, and does not cake, but burns with great heat, and leaves little ash; *cannel*, a compact variety, also bituminous, burns with a clear flame, does not cake, and leaves a whitish ash, principally used, where it can be obtained, for the manufacture of gas. All these varieties are less or more bituminous; but there is another variety, known by the name of *anthracite*, or 'blind coal,' which is non-bituminous. This anthracite has a glistening and semi-metallic aspect, does not soil the fingers when rubbed, and burns without smoke. It is, in fact, a natural coke, or charcoal, the original coal having been deprived of its bituminous products by heat or other causes. It is found in small patches in several coal-fields in contact with the igneous rocks, which have evidently produced the change, but abundantly in South Wales, where it occupies a considerable area. It is used exclusively in the reduction of the metallic ores, for which it has been employed only since the introduction of the hot-blast process. Several fields, both of bituminous and anthracite coal, occur in Ireland; but comparatively little is raised, and almost all the coal used in Dublin, Belfast, and other large towns is imported from England.

Besides the supply obtained in Britain, there are coal-fields, less or more extensive, in France, Spain, Belgium, and Germany; in India, China, the East India Islands, Australia, and New Zealand; in Nova Scotia, and the states of North America; in the Isthmus of Panama, Chile, and Peru; and even in some of the islands of the Pacific and Arctic Oceans. Of these fields, the North American are by far the most extensive and important, presenting areas of bituminous and anthracite coal greater than the whole extent of our own island. That of Pennsylvania, Virginia, and Ohio, for example, extends continuously from north-east to south-west for a distance of 720 miles, its greatest breadth being 180 miles; its area thus amounting to 129,600 square miles. That situated in Illinois, Indiana, and Kentucky, embraces an area of 14,000 square miles; while several, many times larger than the largest coal-field in Britain, are found in Michigan and other parts of the Union. Many of the coal-fields in the world are yet untouched; it being only after the wood of a new country has been used up, and civilisation made some progress, that man betakes himself to the difficult and often dangerous task of extracting mineral fuel. All the coal-fields now mentioned belong to the same great formation; but there are other patches of a more recent date which are occasionally worked, as the lignite, or brown coal of Germany, and of Bovey Hayfield, near Exeter. This, however, is a very different material in comparison, and is only had recourse to where the lower formation is absent, or at such a depth as to preclude its easy working. Taking, therefore, an estimate of the whole amount of coal known to exist, there need be no dread of the supply being exhausted for thousands of years to come; for though the fields of one country should be exhausted, the fields of another lie patent to the same commercial influence which imports tea from China, cutlery and cloth from Britain, and cotton from America.

Coal being, in every instance, a true stratified rock, the modes of obtaining it are much the same in the different countries where it is sought after. In early times, our ancestors could avail themselves of little more than the mere outcrop—that is, that portion of a seam which approaches the surface—and this was excavated just as a stratum of limestone or sandstone is quarried at the present day. By and by, they sank to greater depths, but still entering in a slanting direction, after the dip or inclination of the strata, and not descending by shafts or perpendicular pits, as is now the practice. To rid their workings of water, they hewed long tunnels or subterranean drains from some low level, and carrying this forward to the seam of coal, effected a drainage to that depth. Where the coal-seams lay on high ground, and where there was any deep glen or ravine in the neighbourhood, such drainage often allowed them to work at a considerable depth; but these *day-levels*—so called from their discharging their contents to the open day, in contradistinction to other levels within the mine—were, upon the whole, but imperfect and expensive affairs. In some instances, where pits were sunk, windmills were erected for the purpose of pumping the water; but no certain effect could be calculated upon from an agency so unstable as the wind. The invention of the steam-engine soon set aside these rude and imperfect appliances; shafts, instead of slanting adits, are now everywhere sunk, and the water brought to the surface at once, no matter whether the depth be 30 or 300 fathoms. Of course the fittings of a coal-mine depend, as do all other commercial speculations, upon the value of the material sought to be obtained. In some districts, the shafts are of no great depth, the pumping-engines small and rude, and the mineral brought to the surface simply by animal power; while in other localities the shafts are of enormous depth and finely executed, the engines of great magnitude and superior finish, and no animal power employed unless in the hewing of the coal. In Britain, a Newcastle colliery may be taken as the most perfect of its kind. Here the shafts, which are often sunk at vast expense, vary from 150 to 300 fathoms in depth, are lined with casings of stone, wood, or iron, and are divided into various compartments for the accommodation of the pumping-gear, and the ascending and descending corves which contain the coal—these compartments also subserving an important end in the ventilation of the mine. Having reached the stratum of coal, which generally lies at a considerable inclination, main *drifts* or excavations are made in different directions for drainage, transit, and ventilation; and then the minor workings branch off from these, care being taken to leave pillars or masses of the stratum for the support of the superincumbent material. The water that oozes from the workings finds its way to the lower level, or *sump*, of the pit's bottom, from whence it is pumped up by a powerful engine; and the coal hewn out is brought from the various workings to the main drifts, whence it is dragged by ponies to the bottom of the shaft, and raised in corves, or baskets, to the surface.

Were the accumulation of water the only obstruction to the mining of coal, the difficulty could be easily surmounted. A supply of fresh air, however, must be regularly and unceasingly maintained in every part of the workings; and not only so, but care must be taken to prevent the accumulation of two gases most destructive to human life—namely, carburetted hydrogen and carbonic gas—the *fire-damp* and *choke-damp* of the miners. For this purpose, the various underground workings are so arranged and boarded off, that while one set receives the descending current, another carries it forward again to the pit bottom, where, by means of rarefaction, produced by a huge fire, it is carried up the shaft to the atmosphere. By these means, not only is fresh air supplied to the miners, but the deleterious gases are carried off, and the whole subterranean recesses rendered safe and healthy. The most ingenious of human inventions are, however, imperfect; and fire-damp will exude from the coal-seam, and lurk in recesses, there either to suffocate the first comer, or to explode the instant that a lamp is brought in contact. To prevent these casualties as much as possible, various air-tight trap-doors and boardings are employed, and the miner is furnished with safety-lamps of various constructions, which, while they afford sufficient light, prevent the carburetted hydrogen from coming in contact

with the flame within (see fig. on preceding page).* These remarks apply in particular to the Newcastle coal-field, where, in consequence of such difficulties, coal-mining is conducted with greater care and skill than in any other district; but it must be remembered that there are many fields where fire-damp is unknown, and where the most ordinary ventilation is sufficient to prevent the accumulation of any obnoxious gases. In some of the largest Pennsylvanian mines, the anthracite is of great thickness, and so exposed and level, that it is hewn out either in open quarry or in huge drifts, precisely after the fashion of our railway tunnels.

The value of the coal actually brought to the surface in Britain amounts annually to upwards of ten millions of pounds sterling, and almost the whole of this is derived, although in unequal proportions, from the Newcastle, the South Welsh, the Staffordshire, and Scotch coal-fields. With regard to the first of these—the Newcastle coal-field—it is said that upwards of six millions of tons are there annually raised up out of the bowels of the earth; that 60,000 persons are employed in the mining operations; that 1400 vessels are constantly engaged in conveying the coal—amounting to three millions of tons—required for the consumption of the metropolis alone.

As to the origin of coal, no matter what the variety, there can be no doubt that it is essentially vegetable. Not only are fossil trunks, branches, leaves, and fruits found in the mass, but when submitted to the microscope, it often shews the ducts and fibres of a true vegetable structure. We know, moreover, that vegetable matter, when subjected to moisture and pressure, and excluded from the action of the air, will in a short period pass into a bituminous or carbonaceous mass, which time and greater pressure and heat would by and by convert into true mineral coal. Peat, were it excluded from atmospheric influence, would soon pass into a species of coal: brown coal and lignite, in which the trunks and branches of the trees are still perceptible, are only varieties less perfect than the true coal; and even in the old coal-formation itself, various beds present various degrees of perfection, according as the vegetable mass seems to have been more quickly and perfectly removed from the action of the atmosphere. How the masses of vegetable matter were accumulated, is still a subject of speculation with geologists—some contending that the trees, grasses, ferns, &c., which compose it, must have grown and accumulated just as peat-mosses do at the present day, and that the land was then submerged, and the mass covered over by layers of sand and mud, which, hardening, formed strata of stone and shale; others reject this theory as untenable, and consider the whole strata—sandstone, shale, &c.—of the coal-measures to have been deposited in estuaries liable to periodic inundations, like those of the Niger and Ganges, but only on a more gigantic scale. According to this notion, which is more in accordance with the phenomena presented, coal is partly composed of vegetables which grew *in situ* in the form of jungle, and partly of masses drifted down from the interior by the waters of the river.

In the autumn of 1853, a lengthened jury-trial took place in Edinburgh, in reference to a peculiar mineral found in large quantity near Bathgate, in Linlithgowshire, and the point at issue was, whether the said mineral *was coal*, or *was not coal*. Two names were given to the substance—namely, 'the Boghead Coal,' and 'the Torbanehill mineral;' and the greater number of the professional chemists, botanists, microscopists, geologists, and mining engineers of Great Britain, as also managers of coal-pits, and even working colliers, gave evidence on the one side or the other. The substance under dispute is a hard slaty-looking mineral, with a more or less earthy-brown colour. When an iron instrument is drawn across it, a light-coloured streak is produced, which is not at all lustrous. Certain parts reduced to powder have a yellow tint resembling mustard; other parts yield a much darker powder. Its fracture is at times conchoidal, and at other times slaty. When heated in a close vessel, as in a gas-retort, the Boghead Coal gives off a very large amount of gas of excellent quality, and leaves behind a coke or residue to the extent of about 30 per cent. This coke contains only two or three parts of carbon, and the remainder—27 or 28 per cent. of the original mineral—is composed of white ash or earthy matter. Now, the parties who advocated that the material in question was *not coal*, contended that all true coals had a lustrous streak, and left, when heated in a retort, at least 50 per cent. of coke, of which not more than 10 per cent. was ash; at the same time, they recognised a class of *bituminous shales*, into which they threw the Boghead mineral and all other combustible minerals having more than 10 per cent. of ash. On the other hand, it was asserted that a lustrous or non-lustrous streak was not characteristic of coal; that a difference of 10, 20, or more per cent. in the proportion of the ash was no sign whereby to determine definitely what was coal; and that, however convenient it might be to recognise in commerce a class of combustibles styled bituminous shales, yet all such shales were in reality mere varieties of coal. In short, they considered that under the term coal, those substances must be comprised which consist of compressed and chemically altered vegetable matter, associated with more or less of earthy substances, and capable of being used as fuel. The jury, upon deliberation, agreed with the latter view, and returned a verdict that the Boghead mineral was a coal.

Jet—Amber.

Though the chief use of coal be doubtless that of producing heat and light, there are certain minor purposes to which some of the varieties are applied. Thus we have occasionally seen very pretty vases, and other ornaments, made from cannel-coal when it is sufficiently compact and lustrous. It is easily turned on the lathe, and takes a polish which is not readily tarnished; the only objection to its use being brittleness, and liability to be injured by fire.

Jet, of which necklaces, ear-rings, and other ornaments are made, is but a variety of coal, as common in its origin and nature as that which we pile on our fires. It is occasionally found in the lignite beds of England, but principally in Germany and Prussia, where it occurs associated with amber, which is regarded as a fossil gum, while jet seems to be the trunk and branches of trees more completely bituminised, and freer from earthy impurities than cannel or other coals. It is easily turned on the lathe, or cut with the chisel, and is susceptible of a fine polish. Imitations of jet are extensively manufactured by the glass-maker; but these may be readily detected by their greater hardness and weight.

Amber, a well-known yellow resin-like substance, is a fossil gum or resin. It is solid, brittle, commonly

* The safety-lamp, invented by Sir Humphry Davy, and introduced to the miners in 1816, consists of an oil-lamp enclosed in a wire-gauze cylinder, of which the apertures are extremely minute—a square inch of the surface containing 625 openings. Through apertures so small, flame will not pass, and the lamp may therefore be carried into the most explosive atmospheres without risk. When the fire-damp is to the air in the proportion of 1 to 5, 6, or 7, the cylinder is filled with the flame; but even though the wire-gauze should become red-hot, the exterior air is not kindled. If the miners would always employ this safeguard instead of candles, there can be little doubt that fewer explosions would occur; but the feeble light which it affords renders it unacceptable, and men will actually risk their lives for the sake of a little more light and the avoidance of a little trouble. In many pits, a *locked* Davy is delivered to the pitmen, who return it to the overseers before leaving the pit.

transparent, and, when rubbed, becomes electrical. It is found in various countries, more particularly on the Adriatic and Sicilian shores; on the Baltic, between Memel and Danzig, where there are regular mines of it; and in Japan, Madagascar, and the Philippine Islands. It is used chiefly in the manufacture of beads, necklaces, trinkets, and various ornaments, for which purpose it is easily cut, and takes a beautiful polish. Dissolved by drying linseed oil, it forms amber-varnish. The largest known specimen of amber was found near the surface of the ground in Lithuania, about twelve miles from the Baltic. It weighs eighteen pounds, and is in the royal cabinet at Berlin. Other curious specimens have been detected enclosing insects, and even drops of liquid.

Naphtha—Petroleum—Asphalt.

Naphtha, petroleum, mineral pitch, and asphalt, may in a great measure be regarded as members of the same class, as they are composed of the same elementary substances, carbon and hydrogen. Naphtha, on exposure to the air, soon loses its limpid appearance, and passes into a kind of petroleum; and petroleum, under similar treatment, dries and shrinks into a viscous slaggy state, undistinguishable from native mineral pitch.

Natural naphtha is a limpid, or but slightly coloured bitumen, highly inflammable, and of a strong bituminous, but not disagreeable odour. It is found at Baku on the Caspian, at Hit on the Euphrates, and at other places in Mesopotamia: it occurs abundantly in the lower districts of the Burman Empire; exists at various places in the north of Italy, as Piacenza, Modena, &c.; and in some districts of North America. It generally exudes from fissures in the rocky strata, or is collected in shallow wells, dug in the clays and shales where it occurs. A similar liquid can be obtained by distilling petroleum, coal-tar, and other bitumens; but the artificial product has a more penetrating and unpleasant odour. Naphtha has the property of dissolving most of the essential oils and resins, and is at present largely used as a solvent of caoutchouc. It is also used for lamps; and the cities of Parma and Genoa are said to be lighted with the produce of the wells in the duchies of Modena and Parma. A very fine black pigment may be prepared from the soot of naphtha lamps.

Petroleum, or rock-oil, is another liquid bitumen, of a brownish colour and variable consistency, and yielding a strong disagreeable odour. It is found exuding from various secondary strata, but chiefly in coal districts, where it is evidently a product of that formation. It occurs in small quantities in various localities of Britain, but abundantly in other countries of Europe, in Persia, the Burman Empire, in Texas, and in the islands of Trinidad and Barbadoes. On exposure to the air, petroleum thickens, and assumes a darker hue, in which state it is generally known by the name of mineral pitch, or Barbadoes tar. On further exposure, and especially when mingled with earthy impurities, it passes into a solid state, then becoming the common asphalt or bitumen of commerce. In its ordinary liquid state, it is burned for light; worked into balls with earth and gravel, it is used in Eastern countries as fuel; and mingled with grease, it is occasionally employed as a substitute for tar in coating vessels.

Asphalt, so called from its adhesive nature, differs from mineral pitch in being solid and brittle at the ordinary state of the atmosphere. It melts easily, and is highly inflammable, leaving, when pure, little or no ash after combustion. It is found in most of the localities where petroleum springs occur, being nothing more than their accumulated produce. The chief supplies are obtained from the shores of the Dead Sea, from Barbadoes, from Trinidad, where it occupies a basin or lake about three miles in circumference, and from Clermont, Seyssel, and Bourg in France, where it occurs in limestone and calcareous shales. Asphalt was employed by the ancients in some of their cements, and also in the process of embalming. It is now extensively used in the formation of pavement, roofing, and other economical purposes. Melted and mingled with properly sifted gravel, or iron slag, it forms a very durable and unexpensive pavement, being liable to be softened, however, during intense heats.

CALCAREOUS SUBSTANCES.

Under this head we include such economic minerals as contain a notable proportion of *calx* or lime in their composition. Common limestone, magnesian and lithographic limestones, marble, chalk, marl, gypsum, and alabaster, are familiar examples. Some of these have evidently been deposited from calcareous waters; others are as evidently the production of animalcules, like the coral polype; and some are almost wholly composed of the shells of mollusks and of other calcareous exuviæ. Whatever may have been their several origins, they have all undergone certain structural changes since their formation—thus rendering them less or more compact and crystalline, producing a dull massive rock or a brilliant marble, an opaque gypsum or a translucent alabaster. Chemically, they have one common basis—namely, *calcium*, a substance obtained with difficulty in the laboratory, and never found as a natural product. It is one of the metallic elements discovered by Davy, and so extremely oxidable, that on exposure to the air it is almost instantaneously converted into lime (oxide of calcium); and this lime, if further exposed, becomes a limestone or carbonate of lime, by absorption of moisture and carbonic acid.

Common Limestone.

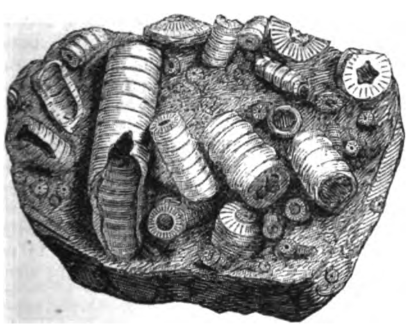
Limestones fit for building and agricultural purposes are found in every formation, from the oldest to those of the most recent origin—being crystalline and concretionary in the primitive and transition series, but gradually losing this structure, and becoming more earthy in the secondary and tertiary strata. In all of them there is a certain amount of impurities, consisting for the most part of clay and sand, with traces of iron and other ingredients. The economic value of any limestone, as well as its fitness for any particular purpose, must depend therefore upon its actual composition, and not upon its absolute purity as a carbonate. The rock is generally dug from open quarries, but occasionally, when it dips slowly, and is worth the expense, it is followed downward by mining, the greater part of the stratum being excavated, and only portions left at intervals to support the superincumbent material. It is then broken into fragments of moderate size, and conveyed to a kiln, where, being placed in alternate layers with coal or turf, it is roasted, thereby expelling its water and carbonic acid. In the best contrived kilns, the process is carried on continuously; broken limestone and fuel being constantly thrown in at the top, and the burned lime raked out at intervals from beneath. In this state it is known as *shell*, *unslaked* or *caustic lime*, and requires to be moistened with water to convert it into powdery quicklime or *slaked lime*. Occasionally, when the limestones contain a considerable percentage of silica (sand), and the heat been very high, the lime refuses to slake, and is said to be *over-burned;* in other words, a portion of silicate has been formed. Quicklime is a soft bulky powder soluble in water; and what is remarkable, the colder the water, the larger quantity of lime is taken up. Thus a pint of water at 60° will dissolve eleven grains; while at 212°, or the boiling-point, only seven grains are retained in solution. As stated under FICTILE MANUFACTURES and APPLIED CHEMISTRY, quicklime is largely employed in the formation of mortar and cements, in glass-making, leather-dressing, dyeing, and bleaching; and, as will hereafter be seen, its uses are not less important in agriculture, in the purification of gas, in medicine, and other industrial processes. Applied to land, it promotes

the decay of vegetable matter, neutralises the effects of certain hurtful compounds of iron, and serves to liberate potash from the insoluble silicates of that base contained in the soil. Lime-water for chemical and pharmaceutical purposes, is always prepared by agitating cold water with excess of quicklime in a closely stoppered vessel, and then, after subsidence, pouring off the clear liquid. Besides the above applications, a large quantity of limestone is used as a flux in metallurgy, such strata being sought for this purpose as contain but a small percentage of impurities.

Limestone is one of the most abundant of rocks, there being no district of any extent in which it does not appear as a member of one or other of the geological formations. In Great Britain and Ireland, the supply is inexhaustible: it is worked in beds from a few feet to one hundred in thickness; the mountain or carboniferous limestone, which underlies the coal-seams, often exceeding that thickness, and ranging unbroken for many miles in extent.

Marble.

Marble is but a technical term for any species of limestone sufficiently pure and compact to be susceptible of a fine polished surface. No matter what the colour, whether white or black, whether studded with the strange forms of fossils or streaked with the most fantastic veinings, marble is but a carbonate of lime, containing only a few subordinate impurities, which do no more than affect its colours and markings. The best varieties are obtained from the primary and transition formations, in which they occur granular, crystalline, and not unfrequently replete with party-coloured veinings. Pretty enough marbles for slabs and other architectural purposes are sometimes obtained from the secondary formations, these being, in general, curiously marked with the shells, encrinites, and other



Fragment of Encrinital Marble.

corals which are imbedded in the mass. None of these, however, are susceptible of the same degree of polish as the primary marbles, some of which, like that of Carrara, seem almost translucent. Most countries of any extent have varieties of native marbles, which, though inferior to those of Italy and the Archipelago, might still be more extensively used than they are, were it not for the expense in cutting and polishing, and, above all, for the rapidity with which many of them become weathered and tarnished.

Sculptors and architects generally arrange the marbles of a country into some such divisions as the following: —*Uni-coloured*, as the black and white; *variegated*, when marked with irregular spots and veins; *madreporic*, when studded with encrinal or coral markings; *shell*, when only a few shells are interspersed through the mass; *lumachelli*, entirely composed of shells; *cipolin*, containing veins of greenish talc; *breccia*, marbles formed of angular fragments of different composition and colour; and *puddingstone*, when the fragments are round instead of angular. The celebrated marbles of Greece and Rome, such as the Parian, the Pentelic, the Carrara, &c., were of one uniform colour, and only occasionally marked with grayish or greenish veins. Besides these, which were chiefly employed in sculpture, and in the decoration of their public edifices, the ancients indulged in a variety of fancy marbles for minor ornamental purposes—such as black, red, green, yellow, spotted, and veined. The localities of some of these ancient marbles are lost, but inexhaustible supplies of first-rate statuary and architectural marbles can still be obtained from the Archipelago, from Carrara, Genoa, Corsica, Sicily, and other parts of Italy. At Carrara alone, about 1200 men are employed at the different quarries, and at the mills for sawing the marble. The annual rental is calculated at about £28,000, and the value of the yearly exportations of the raw material is not less than half a million. So accessible are these quarries, and so free from flaws is the rock in some portions, that blocks of more than 200 cubic feet can be detached by means rude and primitive compared with quarrying in Britain. The value of the material differs according to the quality and size of the block; large blocks ranging from £2 to £3 per cubic foot.

Many marbles of excellent quality are found in France; in England, they are abundant in the counties of Derby, Devon, and Anglesey, the last being of a green colour; in Scotland, at Assynt, Ballahulish, and in the islands of Tiree, Skye, and Jura; and in Ireland, at Kilkenny and other places. The Kilkenny marble is black, and encloses shells of a whitish colour, which, when cut across and polished, present various circular markings, which add to the beauty of the slab. The United States also furnish some excellent architectural marbles, principally of primary formation. One range, which passes unbroken through several of the states, is perhaps one of the most extensive and valuable primary limestones in the world. It is of a pure white colour, and of a highly crystalline texture, affording blocks of more than fifty feet long and eight feet thick. It is employed in several of the states' public buildings —as, for example, the City Hall of New York, and Girard College, Philadelphia.

The applications of marble are so numerous and common, that we need here merely indicate its use in building, statuary, and monumental erections; in internal decoration, as mosaic-work, mantel-pieces, vases, table-slabs, and other articles of furniture. Party-coloured stones susceptible of a high polish, as porphyries, serpentines, and the like, are commonly but erroneously termed and classed with 'marble'—a term which is applicable alone to rocks essentially composed of carbonate of lime, and susceptible of polish as above described. As limestones, all marbles are consequently corroded and acted upon by acids; while porphyries and serpentines being essentially silicious, are not so affected. Even alabaster, though having a calcareous base, is not in the above sense a marble; but is, as will shortly be seen, a sulphate of lime incorrodible by acids. The preparation of marble as an ornamental material is simple but laborious. The blocks are generally detached from the quarry by sets of iron wedges —blasting by gunpowder being apt to produce rents and flaws where least wanted. They are next reduced by hammer and pick, and finally chiseled into the desired form. Slabs are obtained by cutting the blocks asunder with a thin plate of soft iron, under which sand or grit, liberally supplied with water, acts as the cutting agent. Pieces of moderate size are generally cut by hand; but where the blocks are large, machines of various constructions are employed. Marble-cutting, indeed, is the subject of several patents, in which machinery, moved by steam or water, effects not only plain cutting and polishing, but even mouldings and ornaments of an intricate kind. In polishing, sharp sand, emery, tripoli, and tin-putty are the substances

employed—the workman graduating his material with the increasing smoothness of the surface. The body with which the sand is rubbed upon the marble is usually a plate of iron; but for the subsequent process, a plate of lead is used, with fine sand and emery. The polishing rubbers are coarse linen cloths, wedged tight into an iron planing-tool. Throughout the whole operation, a constant supply of water is indispensable.

Magnesian Limestone—Magnesia.

Magnesian limestone, which appears extensively in England, Germany, and other continental countries, occurs often in beds of great thickness, immediately above the coal-measures, just as the mountain or carboniferous limestone lies immediately beneath. It is usually of a cream-yellow colour, and of very variable consistency, some layers being soft and powdery, others irregularly crystalline and concretionary, and some compact and homogeneous. The compact granular variety is generally known by the name of *dolomite*, after Dolomieu, a French geologist. Magnesian limestone is, for the most part, used as the ordinary carbonates of lime—that is, for agricultural and building purposes—some of the English quarries furnishing an exceedingly durable material. The new Houses of Parliament, for example, are built of a magnesian limestone, that of Bolsover Moor, in Derbyshire, having been selected after the most rigid scientific tests of a commission of inquiry. Besides these uses, some of the more compact and homogeneous schists are employed for lithographic blocks, the chief supply for that purpose being derived from Germany, though lithographic schists are also obtained from the white lias limestone in England. (See LITHOGRAPHY.)

Magnesian limestone is so called from its containing a notable percentage of magnesia—a well-known medicinal earth, commonly obtained by burning the carbonate of magnesia. Magnesium is the metallic basis of magnesia, just as calcium is the base of lime; it is strictly a product of the laboratory, and does not occur in nature. The *calcined magnesia* of the druggist is procured either from this source, or from the bittern of sea-salt, or from the waters of certain springs impregnated with the sulphate of magnesia. The hydrated carbonate of magnesia, the *magnesia alba* of the shops, is also obtained by a chemical process from the sulphate. Natural carbonate of magnesia exists as a component part of many mineral substances, making them feel soft and soapy to the touch. *Sulphate of magnesia* (Epsom salts) is obtained, by a simple process, from bittern, by treating magnesian limestone with dilute sulphuric acid, or from certain mineral springs—as, for example, those of Epsom in Surrey, which give to the salt its most familiar name. This salt is one of the most common and useful in medicine, and is, moreover, the chief source of the other forms in which magnesia is administered.

Meerschaum (German, *foam of the sea*), a substance in great repute among tobacco-pipe fanciers, is an earthy carbonate of magnesia, extremely light, and of a yellowish-brown colour. It is found in various parts of Southern Europe, particularly in Greece and Turkey, where, besides being fashioned into pipe-bowls, it serves also the purposes of a fulling-earth. Germany, however, is the great seat of the meerschaum-pipe manufacture, whence France and England obtain their supplies. The substance is first soaked in tallow, then in wax, fashioned into the desired form, and finally polished with shave-grass.

Chalk.

Chalk, another well-known mineral, is a carbonate of lime of a white or whitish-gray colour, having a soft meagre feel and earthy fracture. It is the last or youngest of the secondary rocks, and constitutes an important geological feature of England—the chalk-hills which form the white cliffs of our southern shores having conferred the ancient name of *Albion* (*alba*, white) upon our island. Calcined like common lime, it is used for manure and cement, in polishing metals and glass, in painting and whitewashing, and in various other processes. For the last purpose it is purified by trituration and elutriation, and sold under the name of *whiting*, or *Spanish white*. The chalk-formation yields also the flint of commerce; but this more properly falls to be considered under the class *silicious substances*. What are called *Drawing-chalks* have no relation to this substance. *Red* chalk, for example, is a clay, coloured with peroxide of iron, found in several localities; and the *French* chalk used by artists is a soft magnesian mineral, allied to steatite. *Crayons* are usually made of fine pipe-clay coloured with metallic pigments.

Marl—Calc Sand.

Marl is one of the most recent calcareous deposits, being in many places still in the course of formation. Though essentially a mixture of carbonate of lime and clay, it occurs in various states of purity, from a marly clay, which will scarcely effervesce under acids, to shell-marl, containing from 80 to 90 per cent. of lime. *Marl-clay*, for instance, occurs as a whitish friable clay, with an admixture of lime, and sometimes also of magnesian earth; the term *clay-marl* is used when the calcareous matter prevails over the clay. *Shell-marl* is almost wholly composed of lime and fresh-water shells, with a trace of clay and other earthy matter, and where solidified by chemical aggregation, is known as *rock-marl*. Marl uniformly occurs in valleys formerly the sites of lakes, or in existing lakes, and seems to be partly derived from the waters of calcareous springs which enter such lakes, and partly from the shells and secretions of the fresh-water mollusks which inhabit them. It is dug from open excavations, and applied to certain soils as a manure, or as a top-dressing for pasture.

Calcareous sand, which consists almost entirely of comminuted shells, is another recent product occasionally employed as a fertiliser. It is found in layers in ancient or raised beaches, and in masses by the sea-shore, where, thrown up by the waves, it often consolidates into beds of considerable thickness. As an instance of its value, Sir H. de la Beche mentions that between five and six millions of cubic feet are annually conveyed from the Cornish coasts, to be spread over the land in the interior as a mineral manure. As shells consist almost wholly of carbonate of lime, with a little animal matter, it would be more advantageous in most cases to reduce them to quicklime, which must be much more energetic in its action as a fertiliser.

Gypsum—Alabaster.

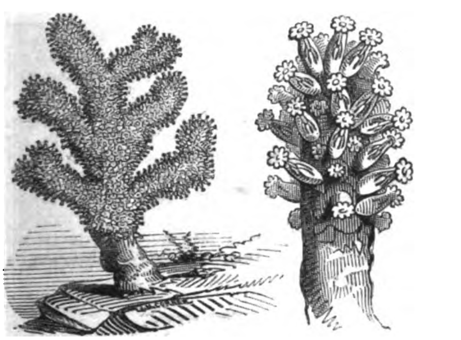
Gypsum, also known as sulphate of lime and plaster of Paris, is found in England, and in many other countries. It occurs in various states of crystallisation and purity: thus the ordinary gypsum of commerce is soft, and imperfectly crystalline; *selenite* is a transparent, highly crystalline mass; *satin gypsum* is fibrous and crystalline; and *alabaster* is pure white, and translucent. Gypsum occurs both in old and new formations, but principally in the new red sandstone, and in the tertiary beds, or those above the chalk. It is mined in various localities in England, and extensively quarried at Montmartre near Paris, whence it has derived its ordinary name of plaster of Paris. Calcined, pulverised, and mixed with water, it is run into moulds, forming stucco images, mouldings, and ornamental fronts for buildings. It is also used for stereotype and pottery moulds, and for medals and casts of various kinds. Mingled with a certain percentage of quicklime, it makes an excellent mortar; its virtues as a fertiliser have been also greatly extolled.

Some of the English gypseous alabasters, such as those of Derbyshire and Staffordshire, stand the turning-lathe

well, and are accordingly formed into jars, vases, and other mantel-piece ornaments. The finest specimens, however, are found near Volterra in Tuscany. These are of a pure white colour and granular texture, and when cut and polished, outrival the finest Carrara marble, from which they are, however, readily distinguished by their softness and liability to tarnish. A large trade in alabaster-work is carried on in Florence, Leghorn, and Milan, where the material is fashioned, partly by the chisel, and partly by the turning-lathe, into statues, vases, lamps, boxes, stands for time-pieces, and other ornamental objects. All sculptures of alabaster should invariably be kept under a glass-shade, as a few months' exposure destroys at once their purity of colour and marble translucency.

Coral.

Coral, or coral-stone, is another calcareous material of commerce, which deserves to be noticed. Being entirely the secretion of certain marine animalcules, it is pretty nearly a pure carbonate of lime, and occurs in the warmer latitudes of the Pacific in vast barriers and reefs, often from fifty to one hundred feet in thickness, and from a few miles to hundreds of leagues in linear extent. Selecting for their residence some submarine ledge of rock, the animalcules begin to ply their vocation, increase, and spread, ever adding to their calcareous secretions, which by and by come to the surface, when they stop and carry on their operations laterally—thus in time elaborating masses which may well compete with any of the ancient rock-formations. (See ZOOLOGY.) There are numerous varieties



Coral.

of the coral animalcule, each variety forming a coral of different shape, but still of the same substance; and ultimately, when indurated by ages, of the same solid and rocky-like consistence. Coral-rock is occasionally employed in the settlements of the South-sea islands as a building-stone, volcanic forces having thrown beds of it several hundred feet above the present sea-level.

The recent branching-corals are solely in request for ornamental purposes—their value depending upon the size, solidity, and colour of the specimen. Black and red varieties are the most highly prized—portions of Sicilian coral having been known to bring as much as eight or ten guineas per ounce. The price, however, is extremely variable, other portions of the same mass selling for less than a shilling a pound. Regular coral-fisheries are established in the Straits of Messina, on the shores of Majorca and Iviza, the coast of Provence, and in other parts of the Mediterranean. Abundant supplies are also obtained from the Red Sea, the Persian Gulf, the coast of Sumatra, &c. The mode of fishing coral, as practised in the Mediterranean, is extremely primitive, but curious:—Seven or eight men go in a boat commanded by the proprietor; the caster throws the net or dredge used to tear up the coral from the bottom of the sea, the rest of the hands work the boat and help to draw the net. This is composed of two beams of wood tied crosswise, with leads fastened to them to sink them: to these beams is fastened a quantity of hemp, twisted loosely round, and intermingled with some loose netting. In this condition, the machine is let down into the sea, and when the coral is pretty strongly entwined in the hemp and nets, they draw it up with a rope, which they unwind according to the depth, and which it sometimes requires half-a-dozen boats to draw.

ARGILLACEOUS SUBSTANCES.

Under this section we include all those substances in which clay (*argilla*) is a prevailing ingredient—as the common clay of the brick and tile maker, the prepared clay of the potter, fuller's-earth, and the slate now so generally used for roofing. Argillaceous compounds occur in every formation, from the lowest slate, through the shales and fire-clays of the coal-measures, up to the plastic clays of the tertiary and superficial deposits. In the earlier formations, they are compact, slaty, and somewhat crystalline; as we ascend, they become dull and merely laminated; while in the more recent deposits lamination disappears, and we are presented with mere tenacious masses, void of anything like structural arrangement. As discovered by Davy, *aluminum* is the metallic basis of pure clay or alumina (oxide of aluminum); but neither the metal nor its oxide is ever found in nature in a state of absolute purity. Sand, lime, magnesia, metallic oxides, and other ingredients, are less or more incorporated with all natural clays; and according to the characters so derived, do they acquire their peculiar values.

Clay.

The common superficial clay, which is so liberally spread over our island, must be familiar to every one. It is of various colours—yellow, red, or bluish; more or less mixed up with sand and fragments of rock; and when softened with water, becomes plastic and tenacious. It is this variety that is ordinarily used for the manufacture of bricks, roofing and drain tiles, chimney-tops, water-tubes, and the coarser sorts of earthenware. For these purposes, it is broken down, partly by exposure to the weather, and partly by the pug-mill, kneaded with water, and freed from the grosser impurities, after which it is beat up into the desired consistency, passed through moulds, dried so far in the atmosphere, and then burned in *clamps* or in kilns. For bricks, slabs, crucibles, &c., which have to resist the action of fire, some of the coal-measure clays are generally had recourse to; these, from their greater purity, and a certain percentage of silica, being susceptible of a more thorough burning. In this case, the raw material requires to be mixed, but generally in connection with the working of coal or ironstone. In England, the Windsor, Stourbridge, and Welsh fire-clays are esteemed the best—the latter yielding those large square slabs employed in the construction of drying-kilns, brewers' coppers, sugar-boilers, furnaces, &c. In the preparation of fire-clays, greater labour and care are necessary—the crude material being generally ground under heavy stone or cast-iron wheels, and in most instances requiring artificial admixture.

Pipe-clay, potters-clay, and porcelain-clay, are but technical names for pure varieties of well-prepared specimens of the same substance. We have seen that common brown ware can be made from ordinary clay; but when the finer varieties of white ware or china are attempted, not only finer clays must be sought, but even these must be mixed with a certain proportion of calcined flint or silex. One of the finest varieties of aluminous earth is the china-clay of Devon and Cornwall, or the *kaolin* of the Chinese. This is a decomposed felspar—one of the constituent minerals of granite—which has accumulated in vast quantities in certain localities, having been no doubt washed down by rains from the weathered and exposed surface of granitic

rocks. At one time, the use of this substance was unknown in England; but now about 38,000 tons—worth about £50,000—are annually exported from the south of England, for the Staffordshire potteries, and for the manufacture of mosaic tesseræ, buttons, artificial gems, and the like. The best pipe-clay is obtained from Poole in Dorsetshire, and the isle of Purbeck; it is employed in the manufacture of tobacco-pipes and fine pottery, and also sometimes used for the fulling or scouring of woollens.

Fuller's-earth.

Fuller's-earth is a soft, dull, unctuous kind of clay, usually of a greenish-brown colour. It is dug in various parts of England, particularly in Buckingham, Surrey, Hampshire, and Bedfordshire, the lighter-coloured beds being the most esteemed. It is used in the fulling of cloth, from its property—a property common to all soft aluminous minerals—of absorbing oil and grease. At one time it was deemed of so much importance to the national trade in woollen, that its exportation was prohibited; but now soap is chiefly used instead, and fuller's-clay has fallen in importance. What the present consumption may be, it is impossible to say; but about forty years ago not less than 7000 tons were annually made use of. Although denominated a clay, it is essentially composed of silicious earth, only about a fourth part being pure alumina; and if the proportion of clay were much greater, it would become too tenacious to be worked by the fuller. Every clay that is of an unctuous or saponaceous quality, will answer in some degree the purposes of fulling, but not so well as proper fuller's-earth, which is distinguished from common clay by its falling to pieces in water with a slight crackling noise, instead of making a paste with it as clay does.

Ochre.

This is a painter's term for a native earthy mixture of alumina, silica, and oxide of iron. It is found of various hues, but chiefly of a yellow or reddish-brown, and is employed as an ingredient in painters' colours, and in the polishing of metal articles. It is obtained from various places, particularly from Shotover Hill, near Oxford; from the coal-measures of the east of Fife; and from Italy. The quantity raised in Britain is unknown, but about 5000 hundredweights are said to be annually imported. In general, ochre is obtained by a rude sort of mining, and requires to be prepared for use by trituration and elutriation.

Clay-slate.

Clay-slate, of which roofing and writing slate are the most familiar examples, is very extensively diffused, and as extensively made use of in the British Islands. It belongs to one of the lowest or oldest formations, is essentially composed of alumina and silex, has a peculiarly fissile structure, and is usually of a dark lustrous blue, bluish-green, or purplish colour. Like all mixed rocks, the chemical composition of clay-slate varies considerably. The following is given as the analysis of a common Scotch variety: Silex, 50; alumina, 27; oxide and bisulphuret of iron, 11; potash, 4; magnesia, 1; carbon, a trace; and water, 7. The principal quarries are in Wales, where they give employment to nearly five thousand hands; in the north of England and west of Scotland; the most extensive being in Caermarthen near Bangor, in Borrowdale in Cumberland, and at Easdale and Ballahulish in Argyleshire. The beds of clay-slate are often of great thickness, but only certain portions are sufficiently compact to be of commercial importance. The chief consumer of this material is the slater, though considerable quantities are also used as pavement in cellars and warehouses, for shelves in dairies, for the construction of cisterns, and the like. The finer-grained varieties are polished for school-slates and slate-pencil; and those of attractive colours are now manufactured into flower-pots, vases, fancy-tables, and other ornamental objects.

Clay-slate is invariably quarried; and here it must be observed, that the splitting of the rock does not take place in the direction of the bed, but at a considerable angle to the plane of stratification. This peculiar structure is known as *cleavage* (see GEOLOGY), and seems to have been superinduced long after the deposition of the strata. It is totally different from *lamination*, which allows certain sandstones and shales to be split into thin slaty bands, and which is a natural structure of deposition, always parallel to the plane of stratification. A piece of slate being split to the desired thickness, it is next squared by a knife, or cutting-edge of steel, the slate being held over a similar cutting-edge or anvil. Polishing is performed by sand, emery-powder, and water; and some varieties of slate stand to be sawn, planed, and turned by tools differing little from those of the joiner. The following is generally given as a test of the fitness of slates for roofing and other external purposes: —Lay one in an oven till perfectly dry; weigh it, and then immerse it in water for some time. When taken out, wipe it carefully with a dry cloth, and weigh it again. Those slates which have acquired the least additional weight, and consequently have absorbed least water from being the least porous, are the fittest for roofing. Good slates should be thin, dense, and of a smooth surface. Balance one on the finger, and strike it with a hammer; if the sound is clear, the slate may be considered as firm; if dull, the slate is less dense, and should be rejected. *Whet*, *polishing*, and other varieties of slate, are treated under the following section.

SILICIOUS SUBSTANCES.

Silex or silica is one of the most important and most generally diffused of the mineral ingredients that enter into the composition of the rocky crust of the globe. Rock-crystal, quartz, chalcedony, and flint, may be regarded as nearly pure silica; and all the varieties of sandstone, quartz-rock, and granite, are in a great measure composed of it—many sandstones, for example, being pure granular quartz or silica, with a slight argillaceous cement. As in the case of the alkaline earths, it has been shewn that silica is an oxide, the basis of which is *silicium* or *silicon*—a substance more closely allied to boron than any other substance, but probably not metallic.

Quartz—Rock-crystal.

Quartz and quartz-rock, though of importance as forming the bases of other rocks, are of themselves of no great commercial value. Pounded quartz, as stated under FICTILE MANUFACTURES, enters largely into the composition of Chinese porcelain, performing the same part as calcined flint in the wares of England. The purer varieties of rock-crystal are occasionally cut as ornamental stones; and of late the transparent and colourless varieties have been pretty generally adopted by opticians as spectacle lenses. Their extreme hardness renders them more durable than glass, and less liable to be scratched, while they are altogether cooler and more agreeable. The so-called Brazilian pebble, used for this purpose, is of pure silica, and is sometimes found in crystals as large as a cocoa-nut. Quartz, in its crystalline forms, constitutes several of the 'Precious Stones,' or gems, and will be further treated under that head.

Flint.

The common nodular flints found in the chalk-formation are nearly pure silica, exhibiting but a trace of alumina, oxide of iron, and lime. The formation of flint within a mass so different in composition as chalk, is still, in some respects, an unsolved problem in geology. It occurs in nodular masses of very irregular forms and of variable magnitude, some of these not exceeding an inch, others more than a yard in circumference.

Although thickly distributed in horizontal layers, they are never in contact with each other, each nodule being completely enveloped by the chalk. Externally, they are composed of a white cherty crust; internally, they are of gray or black silex, and often contain cavities lined with chalcedony and crystallised quartz. When taken from the quarry, they are brittle, and full of moisture, but soon dry, and assume their well-known hard and refractory qualities. Flints, almost without exception, enclose remains of sponges, alcyonia, echinida, and other marine organisms, the structures of which are often preserved in the most delicate and beautiful manner.

The uses of flint are various: calcined and ground to a powder, it is used in the manufacture of the finer sorts of pottery and porcelain; it also enters into the composition of flint-glass; is employed in the preparation of certain kinds of soap; and before the invention of the percussion-cap, gun-flints were in universal use. Flints also form excellent building materials, because they give a firm hold to the mortar by their irregularly rough surfaces, and resist, by their hardness, every vicissitude of weather. The counties of Kent, Essex, Suffolk, and Norfolk, according to Dr Ure, contain many substantial specimens of this sort of masonry. The reduction of flint to economical uses is extremely simple. We have stated how it is prepared for the potter and glass-blower (FICTILE MANUFACTURES); the formation of gun-flints is a process strictly mechanical, and depends wholly on dexterous manipulation.

Sandstones.

Sandstone, or freestone, as it is sometimes called, occurs in innumerable varieties, differing in colour, in composition, fineness of grain, and compactness. Thus, we have some red, from the presence of peroxide of iron; some silvery and glistening, from the presence of minute scales of mica; others white, yellow, and mottled; and some almost jet-black, from the presence of bituminous or carbonaceous matter. As to mineral composition, there is no other class of rocks so varied; for though quartz grains give to them their family character, clay, lime, mica, carbon, iron, and the like, mingle with them so capriciously, that it is impossible to find any two strata of sandstone exactly of the same composition. Again, their texture is equally if not still more varied; in some the grains being as large as pease, in others quite impalpable; some being so soft and friable as to be rubbed down by the hand, and others so hard and compact that nothing but the chisel of the stone-cutter can touch them.

In England, where bricks form the more available material for the construction of houses, there are comparatively few freestone-quarries of much importance. Those of Portland Isle, which have furnished the stone for St Paul's and other public buildings in London, those of Bath, and of Gateshead Fell, near Newcastle, are the most extensive and valuable. In Scotland, freestone of excellent quality is to be found in most localities, and consequently it is the prevailing architectural material. The best strata are those belonging to the coal-formation—such as are quarried in the neighbourhood of Glasgow, Linlithgow, Edinburgh, and in several parts of Fifeshire. The principal buildings of the New Town of Edinburgh are constructed of this material. Good building sandstone is also obtained from the old red formation, such as is quarried at Kingoodie, and other places near Dundee, the rock being at once exceedingly durable, and producing blocks of any dimensions.

Many sandstones are likewise used as pavement, those being sought for that purpose which are at once compact and thin—bedded or schistose. By far the most valuable of this kind are the Forfarshire gray micaceous flagstones, now so generally employed as foot-pavement in all our large towns. A very extensive trade in these is carried on at Arbroath and Montrose, the flagstones being now dressed and hewn by machinery at the quarries. Another excellent material, still more durable, but exceedingly hard and refractory, is also obtained from Caithness. Pavement of average quality is likewise obtained from the coal-measures; but being of a softer and more absorbent texture, is not so well adapted for outdoor purposes. All these beds are highly fissile or schistose, occurring in laminæ or layers of from one to fourteen inches in thickness; and thus accounts for the fact, that at one time the thinner sorts were used for roofing, under the name of *tile-stones*, or gray-slate.

Besides building and paving, several sorts of sandstone are employed for grindstones, millstones, whetstones, and the like. Thus the quarries of Gateshead Fell, situated on the *millstone grit*, or quartzose sandstones of the lower coal-measures, furnish the grindstones known in all parts of the world as 'Newcastle grindstones.' Good millstone and whetstone beds are found in various other places, as are also varieties fit for the wheels of glass-cutters and cutlers. The stones chiefly used in Sheffield are procured at Wickersley in Yorkshire. The celebrated *burr* millstones of France are obtained from the upper fresh-water silicious limestones of the Paris basin, and are not strictly sandstones, in the usual acceptation of that term. A close grit, containing a certain amount of talc, is quarried at Coxgreen, in the neighbourhood of Newcastle, and highly prized as a firestone in the erection of glass-furnaces.

Sand.

On narrowly inspecting the immense masses of sand scattered over the surface of the country, it will be found that the great bulk of it is composed of silicious particles, evidently derived from decomposed quartz-rock, granite, sandstone, and the like. As might be expected, most sands are mingled with clay, lime, and other earthy impurities; and it is according to their silicious character, and degree of purity from earthy ingredients, that they become of value in the arts. Thus sharp, well-sifted sand is an indispensable ingredient in well-prepared mortar, without which the builder, the plasterer, and fresco-painter could not proceed a single step: the commoner sorts are widely used in paving, in the construction of ovens, kilns, annealing furnaces, and the like, where heat is wished to be retained; and some peculiar varieties are much used in the preparation of moulds for the casting of iron, brass, and other metals. Good silicious sand is an indispensable ingredient in all sorts of glass, now one of the most important manufactures in the civilised world. The most valuable sands for this purpose are those of Aumont, near Senlis, in France, and those of the Isle of Wight, and of Lynn, in Norfolk, in England.

Granitic Rocks.

This term may be considered as embracing not only the true igneous granite, but the gneissose and mica-slate rocks, which, though stratified, partake of the same mineral character, and are usually associated with it. In all of them, silica is a predominant ingredient, imparting those hard and durable qualities which render them of economical importance. Ordinary granite is a crystalline compound of quartz, felspar, and mica; but other minerals, such as hornblende, hypersthene, &c., occasionally mingle with it, thus producing a number of varieties. The small-grained grayish granite of Aberdeen is essentially a compound of quartz, felspar, and mica; that of Peterhead is the same compound, rendered red by the oxide of iron contained in the felspar crystals. Granitic compounds are very widely distributed, forming the fundamental rock of our principal mountain-chains. The Grampians in Scotland, the Cumberland and Cornish hills in England, the Wicklow Mountains in Ireland, the Pyrenees in Spain, the Dofrefeld in Norway, the Ural in Russia, the Abyssinian and other African ranges, and the Andes in South America, are all less or more composed of rocks partaking of a granitic character.

The economical uses to which granitic rocks are applied are by no means unimportant. Compact granite, from its extreme hardness, is largely employed in the construction of docks, piers, light-house foundations, bridges, and other structures where durability is the main object in view. Waterloo Bridge in London, the Liverpool and other English docks, are built of granite. It is the ordinary building-stone in Aberdeen, and is largely used in the metropolis for paving. The Pyramids, though internally constructed of limestone, are externally coated with granite. Pompey's Pillar, and other ancient Egyptian structures, are composed of it; the column of Alexander, and the pedestal of the colossal statue of Peter the Great, in the Russian capital, as well as several monumental monolithes in other countries, are also of granite. Within these few years, the granite of Aberdeenshire has been brought into use as an ornamental stone; and machinery has been erected, both at Aberdeen and Peterhead, for the purpose of polishing it like marble, to which many prefer it, for chimney slabs, vases, pedestals, pillars, &c. When uniform and compact in grain, it is susceptible of a very high polish; and has this advantage over marble, that it is not easily stained or scratched, nor at all acted upon by acids.

Serpentine, or the magnesian rock generally so called, is one of very varied composition and quality. The noble serpentine of the mineralogist is a green translucent rock, rather soft, but susceptible of a good polish; and if found in sufficiently large blocks, would make not a bad substitute for marble. We have before us a specimen of a beautiful leek-green variety from New Zealand, where it is said to occur eight or ten feet thick, and capable of being raised in blocks of any size. Should this be the case, the houses of our brethren who have made these islands their adopted home need be in no lack of interior decorations. Potstone, the *lapis ollaris* of the ancients, is another granitic product, easily worked into form, and formerly used for culinary vessels; whence its common designation. *Jade*, sometimes called *nephrite*, from its supposed medicinal virtues, is another dark leek-green mineral of the same family. It contains a larger amount of silica than the true serpentine, which it greatly resembles. In New Zealand and the Indian Archipelago, it is fashioned into hatchets, edge-tools, and other implements.

Mica—Talc—Asbestos.

Mica, talc, asbestos, and other kindred minerals which are the products of the granitic and primary rocks, may be appropriately considered in this place. The silvery-looking, scaly substance which occurs in ordinary granite is mica, so called from its glistening aspect. It is sometimes found in crystals more than a foot square; and when of this size, is split into thin plates, and, from its transparency, used in certain cases as a substitute for glass. It stands a higher degree of heat, without splintering, than glass, and is well adapted for ship-lights, not being liable to fracture during the firing of cannon. The large sheets exposed for sale by the mineral dealers are generally brought from Siberia; hence the term, *Siberian glass*.

Talc, when crystallised, has much the same appearance, but on trial will be found to be less transparent, softer, and non-elastic. Talc-slate, the other form in which this mineral occurs, is a massive mineral, breaking up in tabular fragments; it has a white streak, and greasy or soapy feel. It is employed in the porcelain and crayon manufactures, and is used as a marking material by carpenters, tailors, and others.

Asbestos, or amianthus, is a soft mineral, occurring in separate filaments of a silky lustre, and consisting essentially of silica, magnesia, and lime. When steeped in oil, it may be woven into cloth, which is incombustible, and may therefore be purified by fire; hence the terms amianthus (*amianthus*, undefiled) and asbestos (*asbestos*, unconsumable). Cloth of this kind was used by the ancients to wrap the bodies of the dead about to be burned, to prevent their ashes being mixed with those of the funeral pile. In the United States of America, asbestos is sometimes used as a lamp-wick.

Basaltic Rock.

Under this head we include all the basalts, greenstones, whinstones, and traps, which make up the sum of the igneous rocks of the secondary formations. They are essentially silicious—quartz, hornblende, hypersthene, augite, and so forth, entering largely into their composition. Some of the basalts and greenstones dress well under the hammer, and though of a dingy colour, make an excellent building-stone, their durability being equal to that of granite itself. Ordinary greenstone, or whinstone, is a very valuable rock in many districts of Scotland, where it furnishes material at once for houses, fences, drains, and roads. Indeed, no rock is better adapted, or more extensively used, for causewaying, and for macadamised roads it is unrivalled. We have seen some ornamental pedestals in basalt which took on a pretty fair polish; and an elaborately carved Buddhist idol, of considerable size, now in the museum at St Andrews, is of the same material. Some of the trap-rocks stand fire to perfection, and this has suggested their use as oven-soles, where such varieties can be procured.

Volcanic Products.

The mineral products ejected from volcanoes are chiefly lava, obsidian, pumice, scoriæ, and a light impalpable dust, in all of which silica and alumina are the main ingredients. Some of the compacter sorts of *lava* are hardly to be distinguished from the trap-rocks of the secondary formations, and may consequently be employed for the same economical purposes. *Obsidian*—so named, according to Pliny, from one Obsidius, who first brought it from Ethiopia—is a true volcanic glass, of various colours, but usually black, and nearly opaque. In Mexico and Peru, it is occasionally fashioned into adzes, hatchets, and other cutting instruments, or into ring-stones. So closely does it resemble the slag of our glass-furnaces, that in hand specimens it is almost impossible to distinguish the natural from the artificial product. It consists chemically of silica and alumina, with a little potash and oxide of iron. *Pumice*, a well-known volcanic product, is extremely light and porous, and of a fibrous texture; it is harsh to the touch, is usually of a grayish colour, and has a shining pearly lustre. Like obsidian, it is principally composed of silica and alumina, with traces of potash, soda, and oxide of iron. Pumice is quarried and exported in large quantities from the Lipari and Ponza islands, off the coast of Sicily. It is used for polishing metals, glass, marble, wood, ivory, and also in the smoothing of parchment and vellum. *Pozzuolana*, already described under FICTILE MANUFACTURES, is another volcanic product, which has been long and largely used in the preparation of hydraulic cements.

Tripoli, &c.

We include under this head several silicious earths and slates extensively employed in the polishing of metallic surfaces. The most familiar of these are—tripoli (so called from Tripoli in Barbary, whence it was originally procured), polishing-slate, semi-opal, and some of the porcelain earths. The uses of these substances are well known: it is their peculiar origin that confers on them an especial scientific value and interest. It has been established by Ehrenberg, that these and several other rocky masses are not the results of ordinary deposition, but an aggregation of the silicious shells of the minutest animalcules. This is a curious fact: the remains of creatures, individually invisible to the naked eye, forming rocks which, in the course of time, were to figure in the economical applications of the human race! On analysis, a hundred parts of tripoli are found to contain

upwards of eighty of silica, the remainder consisting of alumina, oxide of iron, and water. The *polirschiefer*, or polishing-slate of the Germans, found at Bilin in Bohemia; and the *berg-mahl*, or mountain-meal of the Swedes, said to be mixed with bread in times of scarcity, are substances of similar origin and use. Another species of infusorial earth is said to be occasionally eaten by the North American Indians; it is probably the same as the European mountain-meal. The well-known *rotten-stone* of Derbyshire and other localities is more argillaceous than silicious; it is largely used for giving the final polish to metals, glass, marble, and precious stones.

SALINE SUBSTANCES.

Under this section we comprehend such products as rock-salt, alum, saltpetre, borax, and the like, which are found either as native salts, or are procured by artificial processes from certain mineral substances with which they are combined in nature. Some of these salts are of vast economical importance, and appear to be as indispensable to the progress of civilised life as either coal or iron.

Rock-salt.

The common culinary salt of everyday use is chemically a muriate of soda, or, more strictly, a chloride of sodium, every hundred parts of which are composed of sixty chlorine and forty soda. It exists abundantly in sea-water, constituting more than a thirtieth part of its weight; it is discharged by salt or brine springs—which arise from different geological formations, and are situated in different countries—to the extent of from 20 to 30 per cent.; and it is found in various degrees of purity in beds and irregular masses, from 20 or 30 to more than 120 feet in thickness. Native chloride of sodium is never found in a state of absolute purity, but is always less or more combined with certain salts of lime, magnesia, soda, iron, and alumina; to free it from these impurities, and render it fit for culinary purposes, is the duty of the salt-boiler and refiner.

At one time, salt was largely, and is still to some extent, derived by evaporation from sea-water, by the following simple process:—A reservoir is erected near the sea, into which, at high-water, supplies are taken by means of a pipe extending a good way down the beach. The pipe is generally placed near the low-water mark, in order to get the water from a point as far from the surface as possible, so that it may be the more impregnated with salt, and require less boiling. The pans are built on a range on both sides of the reservoir, from which the water is pumped into them after the impurities have settled. The pans are shallow vessels, made of sheet-iron, about twenty feet long, and twelve broad, with a furnace below. These are contained in a small low-roofed house, the covering of which is of deals, with an opening at the meeting of the roof and the wall, to allow the vapour to escape. When the water is boiling, a little bullock's blood is put into the pan, which brings the impurities to the surface, and allows of their being skimmed off. As the water boils down, more is pumped in; and this process is repeated before the salt is finally drawn. From a pan of 1800 gallons, fifteen or twenty bushels, of fifty-six pounds each, are obtained in this manner, the process requiring about twenty-four hours. The salt is at first very light and floury in proportion to its bulk, and in this state is most appreciated. A still finer article resolving into large crystals—bay-salt—is made with a low fire, and when a longer time is allowed in the evaporation. For use at table, the salt is refined, and usually run into large lumps. The water which remains after the salt is crystallised, called the *mother-water*, contains a considerable quantity of the chloride of magnesium or bittern, chloride of sodium, and sulphate of magnesia.

The process of procuring salt from sea-water is now all but abandoned in Britain, and is only had recourse to in some southern and tropical countries, where the arts of life are still in a rude and primitive condition. The supply is mainly obtained from brine-springs, such as those of Droitwich in Worcestershire; and from the mineral rock-salt, which abounds in the new red sandstone and upper secondary formations. This important mineral product occurs in Cheshire and Worcester in England, at Altemonte in Calabria, Halle in the Tyrol, Cardona in the Pyrenees, Wieliczka in Poland, and in several districts of North America. As brine-springs always issue from saliferous deposits, and are doubtlessly derived from the solution of the solid masses by subterranean waters, we shall restrict our description to the solid rock-salt, taking the mines of Cheshire as a sufficiently illustrative example. These mines, together with the brine-pits of Worcester, not only supply sufficient salt for the consumption of almost the whole of Britain, but furnish an article of export to the extent, perhaps, of half a million tons annually.

In Cheshire, the rock occurs in large quantities in the condition of an impure muriate of soda. The appearance of the rock-salt is by no means of that brilliant character, nor has it the delicate transparency and bright reflecting surface which the reader may perhaps suppose characteristic of it. It is usually of a dull red tint, and associated with red and palish-green marl; but it is still not without many features of great interest; and when lighted up with numerous candles, the vast subterranean halls that have been excavated, present an appearance richly repaying any trouble that may have been incurred in visiting them. At Nantwich, and the other places in Cheshire, where the salt is worked, the beds containing it are reached at a depth of from 50 to 150 yards below the surface. The number of saliferous beds in the district is five; the thinnest of them being only six inches, but the thickest nearly forty feet; and a considerable quantity of salt is also mixed with the marls associated with the purer beds. The method of working the thick beds is not much unlike that of mining the thicker seams of coal. The roof, however, being more tough, and not so liable to fall, and the noxious gases—with the exception of carbonic acid gas—totally absent, the works are more simple, and are far more pleasant to visit. Large pillars of various dimensions are left to support the roof at irregular intervals, but these bear only a small ratio to the portion of the bed excavated, and rather add to the picturesque effect in relieving the deep shadows, and giving the eye an object on which to rest. The intervening portions are loosened from the rock by blasting; and it may be readily understood that the effect of the explosions heard from time to time, and re-echoing through the wide spaces, and from

the distant walls of rock, impart a grandeur and impressiveness to the scene not often surpassed. The great

charm, indeed, on the occasion of a visit to these mines, even when they are illuminated by thousands of lights, is chiefly owing to the gloomy and cavernous appearance, the dim endless perspective, broken by the numerous pillars, and the lights, half disclosing and half concealing the deep recesses which are formed and terminated by these monstrous and solid projections. The descent to the mines is by a shaft, used for the general purposes of drainage, ventilation, and lifting the miners and produce of the mine. The shafts are of large size in the more important works, and the excavations very considerable, the part of the bed excavated being in some cases as much as several acres. Over this great space, the roof, which is twenty feet above the floor, is supported by pillars, which are not less than fifteen feet thick. The Wilton mine, one of the largest of them, is worked 330 feet below the surface; and from it, and one or two of the adjacent mines, upwards of 60,000 tons of rock-salt are annually obtained, two-thirds of which are immediately exported, and the rest is dissolved in water, and afterwards reduced to a crystalline state by evaporating the solution. The modes of working rock-salt are much the same in all countries; while the fineness and purity of the manufactured material depend upon the rapidity with which the brine is evaporated, and the nature of the clarifying agents employed. The uses of salt, whether obtained from sea-water or from mineral products, are so numerous and so well known, that it would be almost superfluous to attempt their enumeration. From its use as a simple condiment, through all its applications in the arts, up to the manufacture of soda from its substance, salt is one of the most important of natural products.

The formation of rock-salt is a subject which has much engaged the attention of speculative geologists. Being found regularly interstratified with sandstones and other beds, it becomes evident that the formation has taken place in some way consistent with the ordinary processes by which sedimentary rocks in general have been formed. The reigning theory as to the origin of salt is, that it is washed out of the land in the course of disintegration, and carried by rivers into the sea, or into detached lakes, all of which, as is well known, are charged with salt, in consequence of evaporation carrying off only the pure water, and leaving the infused matters behind. It is a chemical law affecting water liable to receive such contributions of salt, that it cannot retain in solution more than a certain quantity: so soon as this amount is attained, the salt begins to fall to the bottom. Now, if a group of detached lakes, existing in the era of the New Red Sandstone, had received charges of salt beyond what the water was fitted to retain in solution, depositions like what we find in Cheshire would unavoidably follow; and these would be liable to be covered over with deposits of mud and sand, as casual circumstances might determine. Estuaries cut off by convulsions of the land, and then dried up, would also become basins for the deposit of salt; and probably some of our salt-beds originated in that manner.

Alum.

This is a well-known earthy salt, found native only in small quantities, but very largely manufactured from certain argillaceous strata, generally distinguished as alum-clays and shales. It is composed of alumina, sulphuric acid, potash, and has a sweet and astringent taste, and is a powerful styptic. It is much used in dyeing and in calico-printing, in consequence of the attraction its base has for colouring-matter; it is also used in lake colours, in leather-dressing, in the preparation of paper-pastes, in clarifying liquors, and by candlemakers to harden and whiten the tallow.

Native alum being too scanty a product to be used for any of these purposes, it has become the duty of the chemist to prepare it artificially—either from mineral substances which contain the elements of alum, or by mixing these elements together, so as to lead to their chemical combination. Thus, at Hurlett and Campsie, near Glasgow, it is manufactured from certain of the coal-shales, and at Whitby, in Yorkshire, from strata of alum-slate belonging to the lias-formation; while at Newcastle and in France it is artificially prepared by mixing clay, sulphuric acid, and potash—soda or ammonia being sometimes substituted for potash. In the former case, if the crude ore is hard and slaty, it requires to be calcined and exposed to the air, in order to facilitate its solution in water; if soft, crumbling and efflorescent, calcination is dispensed with. This being effected, it is next steeped till the ore is spent; the liquid is then pumped off, boiled, and ultimately crystallised by adding the potash, without which, or some other alkali, sulphate of alumina does not crystallise. When alum-shale contains sulphate of iron (copperas or green vitriol), which is the case at Campsie, this salt is removed from the concentrated solution before adding the potash to obtain the alum. In the second or chemical mode of manufacture, calcined Cornish clay and sulphuric acid are combined to form the sulphate of alumina, to a solution of which the sulphate of potash is added to induce crystallisation. These different ingredients are allowed to remain at rest in circular vessels, where the alum gradually crystallises round the sides, shooting forth large crystals towards the centre, where the mother-liquor (or uncrystallisable portion) remains. The alum thus produced requires to be further fined or *roched*—that is, dissolved by the action of steam, and again crystallised for the market.

In both of the methods above described, an alkali is used to induce crystallisation; but as the sulphate of alumina is the sole efficient agent in the arts, a process has been invented to produce a 'patent alum,' having all the properties of common alum, but without containing potash. 'In making this alum,' says Mr Dodd, 'sulphuric acid and Cornish clay are used as in the other case; but the clay is used in greater proportion, so as to form a thick paste. This paste is placed in a heated trough, where the moisture is so far evaporated as to convert the mass to the form of a dry earth. From the trough it is removed to tanks, where water is employed to dissolve it; and while in the liquid state, the composition is acted upon by an agent intended to remove any iron that may be in the clay—this being the only contained ingredient which is injurious to the alum. The agent employed combines with the iron existing in the clay, and forms with it Prussian blue. This pigment is allowed to subside, and the remaining liquor, being a solution of sulphate of alumina, is boiled till all the water is driven off. The solid residue is formed into cakes an inch or two in thickness, and in this form it comes into the market. Instead of being a crystal, it is an opaque earthy solid, differing from common alum in containing no potash, but possessing in common with it the properties which render it valuable in the arts. As the Prussian blue is procured in far too large a quantity to be allowed to remain in that state, it is restored again, by chemical means, to the form which it before presented, ready to be again used in making more alum.'

Of the alums manufactured in other countries, the *roche* (so called from Roccha in Syria) is imported from Smyrna, and the *Roman* prepared at La Tolfa, near Rome—either of which brings fully double the price of the British manufacture. Alum is also largely prepared in China, whence India obtains her main supply.

Nitrate of Potash.

This is the *saltpetre* of ordinary language—a salt composed of nitric acid and potash. It is of very varied utility, being used in the manufacture of gunpowder, signal-lights, nitric and sulphuric acids, and in dyeing, metallurgy, curing of meat, and in medicine. The sal-

prunella of the shops is the ordinary saltpetre purified and moulded into cakes and little balls. Our main supply of saltpetre is derived from Bengal, where it exists in the soil, and from which the rough nitre or crude saltpetre of commerce is obtained by washing, evaporation, and crystallisation. From 10,000 to 15,000 tons of this salt are annually imported into Britain. In France, Germany, and other continental countries, the salt is produced artificially on what are called *nitriaries*, or nitre-beds.

Nitrate of Soda.

This salt, sometimes known by the name of cubic nitre, possesses properties similar to those of saltpetre, differing chiefly in being more pungent in taste, more soluble in cold water, and more inclined to attract moisture from the atmosphere. It differs also in the form of its crystals—these being of a rhomboid form, while those of saltpetre are six-sided prisms. It is obtained almost wholly from South America, where it occurs in immense deposits in the high districts of Atacama and Tarapaca in Peru. Indeed, according to Darwin, a great proportion of the surface of the southern regions of South America consists of *salinas*, or salt-plains, from which common salt, and the sulphates and nitrates of soda, might be procured in any quantities—these occurring sometimes as an efflorescence, sometimes in crystallised strata, but oftener mingled with clay, sand, and other earthy impurities. One deposit which he visited in 1835, was full 3300 feet above the Pacific, and consisted of a hard stratum, between two and three feet thick, of the nitrate mingled with the sulphate of soda, and a good deal of common salt. It lay close beneath the surface, and followed, for a length of 150 miles, the margin of a grand basin or plain, which, from its outline, must once have been a lake, or more probably an inland arm of the sea, as iodic salts were abundant in the stratum. This salt was first imported from Iquique in 1830, and so rapidly has its commercial value increased, that, ten years after, about 150,000 hundredweights were shipped for Great Britain alone. In 1835, Mr Darwin found the selling-price at Iquique 14s. per 100 pounds—the main part of the expense being its transport from the mountains on mules and asses. It is principally used as a manure, and as a top-dressing for pasture, its advantages being very perceptible on all but wet plashy soils; it is also used in the preparation of nitric acid, and for many of the purposes to which saltpetre is applied; but, owing to its deliquescent properties, it is not adapted for the manufacture of gunpowder.

Natron.

Natron is a native sesquicarbonate of soda, found as an efflorescence or as deposit in sandy soils in Egypt, Mexico, Hungary, and other countries; hence sometimes called *mineral soda*. At the lakes of Sukena in Africa, this salt is said to form a striated crystalline stratum just below the surface. From these lakes, several hundred tons are collected annually in the dry season, chiefly for consumption in Africa, but sometimes exported to Europe under the name of *trona*. Natron has many of the properties of the two preceding salts, and, according to Herodotus, was employed by the Egyptians in the process of embalming.

Borax.

This compound salt is found native as an efflorescence on the soil, or dissolved in the waters of certain lakes, in Persia and Tibet, in China, Ceylon, and South America. It occurs also in combination with several minerals, and, as might be expected, is given off in solution by hot and thermal springs. It is a compound of soda with a peculiar acid, first isolated by Homberg about the beginning of last century. The acid is now known to be an oxide of an elementary substance, to which the name of *boron* is given (see CHEMISTRY); the acid itself is known by the term *boracic acid*. 'Until the recent discovery of a more advantageous mode of obtaining borax, it was brought to Europe,' says Parnell, 'in considerable quantities from the East Indies. It was imported in small dirty crystalline masses called *tincal*, which contain scarcely more than half their weight of pure borax—the remainder consisting chiefly of a peculiar saponaceous combination of soda with a fatty acid. The salt was never termed borax till purified by some such process as the following:—The crude salt, being placed in proper pans, is covered with cold water to a height of two or three inches above its surface, and allowed to stand for some hours. Recently slaked lime is then added to the amount of one part to four hundred parts of tincal; the mixture is thoroughly stirred, allowed to stand for twelve hours, again strongly agitated, and the troubled supernatant liquid decanted. The liquor is not thrown away, but preserved to wash the impure borax; the solid matters held in suspension being first separated by subsidence and decantation. The washing is continued with the same liquid, clarified by subsidence as often as applied, until it is no longer rendered turbid. In this way, a great portion of the fatty matter may be washed away as an insoluble soap of lime. The salt thus purified is dissolved in two and a half parts of boiling water, and mixed with a solution of chloride of calcium, containing two parts of that salt to one hundred parts of tincal. A precipitate is thereby produced, consisting chiefly of the insoluble soap of lime; the liquor is separated from the precipitate by filtration, and evaporated down to a density of 1·14 or 1·16. It is then run off into crystallising vessels, and cooled very gradually to obtain large crystals.' Such, with some slight variations, was the mode of preparing borax from tincal.

Tincal, however, is now no longer the European source of the salt, which is largely and economically obtained from the boracic lagoons of Tuscany. These lagoons may be ranked among the wonders of the age, and are unique in Europe, if not in the world. They are situated on the sides of hills, and are supplied with water by the condensation in them of volcanic vapours or *soffioni*, highly charged with free boracic acid, together with borate and sulphate of ammonia, and other saline substances. The soil surrounding these beds of hot water is covered with a saline efflorescence, consisting chiefly of boracic acid, but likewise containing in smaller proportion salts of ammonia, borate, and sulphate of alumina, and persulphate of iron. The presence of free boracic acid in these and other volcanic vapours was ascertained towards the end of last century; but it was not till 1816 that an effectual mode of procuring the crystallised product was discovered. The lagoons are now artificially constructed over the soffioni, the continuous discharge from which more largely impregnates the water with boracic acid, and this solution is still further concentrated by ingeniously applying the superabundant heat of the soffioni to evaporate the water. Passing in this manner from reservoir to reservoir, and from evaporating pan to pan, the solution is ultimately allowed to crystallise; and the acid so obtained packed in barrels for exportation. For the conversion of this crude acid into borax, there are several processes in use, the chief objects of which are to get rid of the ammonia and other natural impurities, and ultimately to obtain the pure salt in large and hard crystals.

The applications of borax in the industrial arts are already numerous. Borax is largely employed by brasiers, silversmiths, and other workers in metals, as a flux; by potters in the formation of a glaze for earthenware and porcelain; by chemists as a reagent in blow-pipe analyses; in the preparation of certain kinds of glass, and generally if its price permitted; in the fabrication of artificial gems; in medicine; and in other minor arts.

Baryta—Strontia.

These are two alkaline earths (see CHEMISTRY) very similar to each other, and indeed, till recently, considered identical. The former is an oxide of barium; the latter, of strontium; neither the metalloids nor their oxides are found in nature. The only two abundant natural compounds of baryta are the sulphate, which occurs crystalline, and the carbonate. Sulphate of baryta, or *heavy spar*, is found in various districts, particularly in Cumberland and Westmoreland; a variety from Derbyshire is provincially called *cawk*. The native forms of strontia are the carbonate and sulphate, both found in a crystalline state. The former occurs abundantly in the lead-mines at Strontian, in Argyleshire—hence the name; the latter is found near Bristol, and associated with native sulphur in Sicily.

Sulphur.

Though sulphur or brimstone be an elementary substance, *sui generis*, and, strictly speaking, does not come under the head of saline substances, yet it may, without much impropriety, be considered in this place, as often occurring in efflorescent salts or crystals. It is a yellow brittle mineral product, found in most parts of the world, but most abundantly in volcanic regions, and in the immediate neighbourhood of burning mountains, such as Etna, Hecla, &c. It occurs either as an efflorescence on the surface, or in masses mingled with clay, ashes, and other volcanic products. Our chief supply is obtained from Sicily, where it occurs in beds of a blue-clay formation; and whence it is imported, as dug from the mines, in square masses or blocks, called rough brimstone. Sulphur is also obtained artificially from the sulphurets of copper, iron, and other metals; but the facility with which native material can be secured, prevents its artificial production from being followed to any great extent.

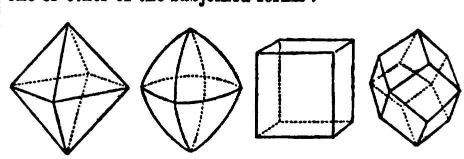
Unlike most other materials of commerce, the formation of sulphur is still going forward wherever volcanic agency is in a state of activity. It appears to be sublimed by the subterranean heat through the crevices and fumeroles of the mountains; and this collects either as a slight efflorescent crust on the surface, or in crystals and in masses throughout the material of the ejected clays, ashes, &c. Speaking of the sulphur mountains of Iceland, Sir George Mackenzie says: 'At the foot of an elevation, in a hollow formed by a bank of clay and sulphur, steam rushed with great force and noise from among the loose fragments of rock. Ascending still higher, we came to a ridge composed entirely of sulphur and clay, joining two summits of the mountain. Here we found a much greater quantity of sulphur than on any other part of the surface we had gone over. It formed a smooth crust, from a quarter of an inch to several inches in thickness: the crust was beautifully crystallised. Immediately beneath it, we found a quantity of loose granular sulphur, which appeared to be collecting and crystallising as it was sublimed along with the steam. Sometimes we met with clay of different colours—white, red, and blue—under the crust; but we could not examine this place to any depth, as the moment the crust was removed, steam came forth, and proved extremely annoying. We found several pieces of wood, which were probably the remains of planks that had been formerly used in collecting the sulphur, small crystals of which partially covered them. There appears to be a constant sublimation of this substance, and were artificial chambers constructed for the reception and condensation of the vapours, much of it might probably be collected.' Such is the usual origin of native sulphur—a substance of greater commercial value to a country like Britain than the most of our readers may imagine. It is employed for making gunpowder, sulphuric acid—which is indispensable to so many manufacturing processes—cinnabar, and for a variety of other purposes in the arts, as well as being used medicinally—requiring altogether an annual supply little short of 20,000 tons. For a further account of the nature and properties of sulphur, and of the manufacture of sulphuric acid, see CHEMISTRY. Orpiment and realgar, the one a yellow, and the other a red sulphuret of arsenic, though found in a mineral state, and as such used in the arts, will be more systematically treated under METALS AND METALLURGY.

PRECIOUS STONES.

All our so-called 'precious stones'—the diamond, ruby, emerald, amethyst, &c.—are but compounds of carbon, alumina, silica, lime, &c., and might therefore, so far as their mineralogical character is concerned, have been considered under the sections already presented. As none of them, however, occur in rocky masses, but rather as crystals, geodes, and concretions within other rocks, and as fashion has generally set a price upon them wholly disproportioned to their utility, it may be as well to treat them as an independent class. Our limits will only permit us to mention a few of the more esteemed; seeing that lapidaries, jewellers, and others, have vastly increased the nomenclature of precious stones by giving individual names to specimens which are, in reality, but varieties of the same substance. For an account of *pastes*, or *artificial gems*, see FICTILE MANUFACTURES; and for *pearls*, native and artificial, which are often erroneously classed with gems, see ZOOLOGY and FISHERIES.

Diamond.

The most highly prized of precious stones is the diamond, a crystalline mineral of unsurpassed lustre and hardness. It is the hardest known substance, and can be polished or cut only by its own dust or powder; hence the common saying of 'diamond cut diamond.' When perfectly pure, it is as transparent as a drop of the purest water, in which state it is known as a diamond of the first water; and in proportion as it falls short of this perfection, it is said to be of the second, third, or fourth water, till it becomes a coloured one. Coloured diamonds are generally yellow, blue, green, or red, and the higher the colour, the more valuable they are, though still inferior to those absolutely transparent. Diamond, as has been demonstrated by numerous experiments, consists solely of carbon, being, in fact, a crystallised charcoal, generally appearing in one or other of the subjoined forms:



Diamonds were originally discovered in Bengal, but they have since been found in other parts of India, in the East India islands, in the Brazils, and recently in the Ural Mountains. They occur chiefly in alluvial deposits of gravel and sand, lying in detached octohedral crystals, sometimes with plain, but more frequently with rounded surfaces. The finest are cut for ornamental purposes into *brilliants*, having curvilineal faces both at top and bottom; or into *rose diamonds*—that is, those having their tops or upper surfaces cut into a number of triangular facets, but quite flat beneath. The black, dirty, and flawy ones, and those unfit for being cut (technically called *borts*), are pulverised for the purpose of polishing others, besides being applied to various uses in the arts. Fractured portions, with good cutting edges, are usually set for glaziers' cutting-pencils, in which state they are worth from twelve to twenty shillings; and also as *drills* for piercing other precious stones. It is the ornamental diamonds that bring the exorbitant

prises so frequently mentioned in modern history, their value depending upon shape, colour, and purity, and being fixed at so much per carat of 3¼ troy grains. The diamond which we know most about in this country is the Koo-i-noor, which is now the property of Queen Victoria, and was exhibited in the Great Exhibition of 1851. This diamond originally belonged to Runjeet Singh, who usually wore it upon his left arm, according to the custom of Eastern potentates, but who often decorated his horse with this and other diamonds to the value of £300,000, the great Koo-i-noor being placed on the pommel of the saddle. When this diamond was exhibited at the Crystal Palace, it weighed 186$\frac{1}{16}$ carats, but it was immediately thereafter reduced, by cutting, to 102$\frac{13}{16}$ carats. To arrive at an estimate of the value of the Koo-i-noor, it is only requisite to multiply 102 (its weight) by 102, and then by 8, which gives £83,232 as its present value. The largest diamond ever known was brought to the king of Portugal from Brazil. It is uncut, weighs 1680 grains, and its value is often quoted at £5,644,800. Similar extravagant valuations are applied to the famous Russian one weighing 193 carats; to that in the possession of the Great Mogul, weighing, cut, 280 carats; and to others; but it does not appear that any sum exceeding £150,000 has ever been given. The last great sale of jewels was in London in 1837, for the distribution of the Deccan booty, obtained by the army under the Marquis of Hastings. On that occasion, the magnificent Nassau diamond, weighing 357½ grains, of the purest water, brought only £7200. The Russian diamond, says another authority, is of the size of a pigeon's egg, and was purloined from a Brahminical idol by a French soldier; it passed through several hands, and was ultimately purchased by the Empress Catherine for the sum of £90,000, an annuity of £4000, and a title of nobility. Perhaps the most perfect and beautiful diamond hitherto found is a brilliant brought from Malacca by a gentleman of the name of Pitt, who, after getting it cut in London, sold it to the Regent, Duke of Orleans, for the sum of £130,000; its weight 139 carats. It is now, or rather we should say was lately, in the crown-jewels of France; its further history is a problem yet to be solved.

The art of cutting diamonds—which is distinct from that of the lapidary or polisher of inferior gems—is thus described by Webster: The gem may be split by a steel tool if a blow be applied; but to effect this it is necessary to have a perfect knowledge of its crystallised structure; and the workman cannot form facets at pleasure by splitting. To produce the faces which are required for exhibiting the gem in all its beauty, the process called *cutting* is resorted to, but which is, in fact, abrasion rather than cutting. For this purpose, the diamond is fixed on the end of a stick or handle, in a small ball of cement; that part which is to be reduced being left to project. Another diamond is also fixed in a similar manner, and the two stones are rubbed against each other with considerable force, until they are ground away as much as is necessary to produce a facet. Other facets are formed in a similar way by shifting the position of the diamonds in the cement. When the faces are thus completed, they are next to receive an exquisite polish. For this purpose the stones are imbedded in soft solder, contained in a small copper cup, the faces to be polished being left to protrude. A flat circular plate of cast iron is then charged with diamond-powder, and the stone is held against this plate, while it is made to revolve till the polish is complete.

Sapphire—Ruby—Topaz—Garnet, &c.

These may be conveniently grouped together as consisting essentially of crystallised alumina — traces of magnesia, silica, fluoric acid, chromic acid, &c., constituting the specific distinctions. The sapphire is of various colours—the *blue* being generally known among jewellers and lapidaries as the sapphire; the *red*, the Oriental ruby, and, next to the diamond, the most valuable of gems; and the *yellow*, the Oriental topaz. Sapphires are sometimes substituted for diamonds, by exposing them to a strong heat, which destroys their colour, but improves their hardness and transparency; and this kind of fraud would be difficult to detect by any one who was not a good judge of these gems.

Corundum, or adamantine spar, is nearly allied to the sapphire, and, with the exception of the diamond, is the hardest substance known. It is almost a pure crystallised alumina, consisting of more than ninety per cent. of that substance, with a little silica and iron. It is found in India, China, and some parts of Europe; and is used in the East for the same purposes to which diamond-powder is applied in England. Emery, so called from Cape *Emeri*, in the island of Naxos, is but a variety of corundum, with an admixture of iron, which gives to it a bluish-gray colour. From its extreme hardness, its powder is largely employed in the polishing of glass and metals, and in the cutting of gems and other minerals—all of which are abraded by it, with the exception of the diamond. Emery-powder is prepared by grinding the mineral in steel mills; it is afterwards assorted into parcels of different degrees of fineness, by agitating it with water, and separating the particles which deposit themselves at different stages—the finest being the last which subside. Emery-paper and emery-cloth are prepared like common sand-paper—namely, by coating the fabrics with a strong size of glue, gum, flour, and alum, upon which the powder is sifted while the size is sufficiently soft to retain it.

The ruby, found chiefly in the sand of rivers in Ceylon, Pegu, and Mysore, is also of various colours—the scarlet-coloured being distinguished as *spinelle ruby;* the pale or rose-red, *balass ruby;* and the yellowish-red, *rubicelle*. Rubies from two to six carats are rare, and when of this size, and of the fine deep cochineal red so much prized, fall little short of the diamond in value. The topaz likewise presents various shades between yellow and wine-colour; but, from its large percentage of silica, is harder than either of the preceding. The best varieties are known as the Brazilian, the Saxon, Siberian, and Scotch.

The garnet, another well-known mineral, belongs to the same section, the varieties being essentially composed of alumina, with silica, magnesia, iron, &c. The most valuable is the *precious garnet*, almandine, or carbuncle, which is commonly a transparent, red, and beautiful mineral, either crystallised, or in roundish grains. It is found in Ceylon, Pegu, and Greenland. The *pyrope*, a blood-red variety, found in Germany and Ceylon, is perfectly transparent, and, in roundish or angular grains, is perhaps next in value. The common garnet is not transparent like the preceding, and is most frequently of a dull-red or blackish-brown. It is found plentifully in Scotland, Sweden, and other countries, where the primitive rocks abound; but comparatively few specimens are fit for the jeweller. The black garnet, or, more properly, *melanite*, is a mineral found in volcanic rocks, and worked into necklaces at Naples.

Emerald—Beryl—Amethyst—Carnelian, &c.

In these the predominant ingredient is silica; they may be called silicious gems, just as the ruby and sapphire might be styled aluminous, or the diamond carbonaceous. The emerald is one of the most esteemed, being of a beautiful green colour, and occurring in prismatic crystals. It consists essentially of silica, with a small percentage of alumina and glucina, the colouring-matter being oxide of chromium. The finest emeralds are brought from Peru and Brazil; the mines from which the ancients obtained their supply are said to have been in Upper Egypt. Fine emeralds are extremely rare; and one of four carats, of approved hue, and well cut, is worth about £160. Beryl differs little

from emerald except in colour—the latter name embracing the green varieties, the former all those that are tinged less or more with yellow or blue, or are altogether colourless. Beryls are found in Siberia, France, the United States, and in Brazil, the latter country furnishing the brilliant variety known as the precious beryl, or aqua-marine. Heliotrope, or *bloodstone*, is another common deep-green silicious mineral, somewhat translucent, and often variegated with blood-red spots—whence its common appellation. It is found in Siberia, in Iceland, and the Hebrides, but chiefly in India, which furnishes the finest specimens. It is in request among the Chinese as an ornament to their girdle-clasps.

Amethyst is a pure rock-crystal, of a purplish-violet colour, and of great brilliancy. It is found in India, in Germany, Sweden, and Spain, but chiefly in Brazil, and is in great request for cutting into seals, bracelets, and brooches. 'Some of the ancient vases and cups,' says Brande, 'are composed of this mineral, and it was an opinion among the Persians that wine drunk out of such cups would not intoxicate; hence its name from the Greek *amethystos*.' The cairngorm of the lapidary is another crystallised quartz, of various hues, and nearly transparent. It derives its name from the mountain Cairngorm in Inverness-shire, and is much used as an ornamental stone in this country.

Agate, chalcedony, opal, carnelian, sardonyx, jasper, and some kindred substances, may be, without much impropriety, regarded as merely varieties of the same mineral, having different colours and degrees of transparency. They are found in most countries, and are used for seals, brooches, cameos,* and other ornamental purposes—the larger geodes or mass being often fashioned into cups and vases. Carnelians and opals are perhaps the most valuable, some specimens of the Oriental opal being worth double the price of a sapphire of the same size. This variety is sometimes known as the Nonnius opal, from the senator Nonnius, the possessor of the famous opal of Rome, worth 20,000 sesterces, who preferred banishment to parting with it to Antony. The *cat's-eye* opal, so called from its presenting an effulgent pearly light, like the changeable reflections of the eye of a cat, is another silicious mineral or quartz, interspersed with filaments of asbestos. It is found chiefly in Ceylon and the Indian peninsula, and is held in great estimation among gem-fanciers. When the late king of Kandy's jewels were brought to the hammer in London, in 1820, a specimen, which measured about two inches in diameter, brought upwards of £400. *Mocha-stone*, also in some repute, is a semi-transparent chalcedony, enclosing various ramified forms produced by oxide of iron, or other metallic substances, but sometimes also by the presence of vegetable bodies, such as mosses. The finest are found in Gujerat, but receive their name from being brought from Mocha. The *onyx*, so much admired by the ancients, is a species of agate, in which the silicious particles are arranged in alternating horizontal layers of opaque white and translucent blue, gray, or brown. It is employed for cameos, the figure being cut out of the opaque white, and the dark part forming the ground, or *vice versâ*. It is most valuable when the colours are in strong contrast, and when the layer is thick enough to give a high relief to the object engraved.

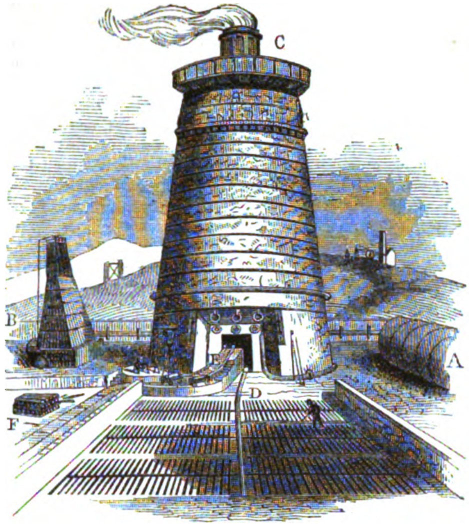
The district of Cambay, in India, yields agates, chalcedonies, carnelians, and jaspers of every variety, and of enormous size; and these, now so common in the market, are known by the general name of *Cambay Stones*. Great numbers of people find constant employment in quarrying these. When first taken from the rock, their colours are faint, and tracings imperfect. They are first exposed for some time to the air, and afterwards heated nearly to redness by a slow fire of wood or cow-dung. Under this process, the colours come out in the greatest brilliancy. They are now cut up by the common lapidaries' wheel, and polished in the usual way with emery or ground corundum. Cutting is but rarely resorted to: in general, the stones are chipped as nearly to the required form as possible, and then ground with emery and polished. They form a considerable article of sale in the Bombay market, and are imported in immense quantities by the London lapidaries, who improve their polish, and alter their forms into such as may be considered most saleable. The Bombay brooch and necklace pieces, paper-folders, finger-rings, shirt-buttons, ear-ring drops, &c., are those most frequently found on sale.

Lapis-lazuli, or azure-stone, at one time held in the highest estimation, is another precious mineral, whose chief constituents are silica and alumina. Its principal localities are China, Persia, and Siberia, where it occurs in massive, but rarely in regular crystals. The finer specimens are prized by the lapidary; but by far the most important application of the substance is to the production of ultramarine—a pigment which, till of late, was more precious than gold. Within these few years, however, the chemist has succeeded in producing an artificial ultramarine, possessing all the properties of the native pigment, and at such a rate that several pounds weight can be procured for what, twenty years ago, would scarcely have purchased a single ounce.

Calcareous Spars.

Several of the calcareous spars are of great beauty and transparency, but in general their softness and frangibility prevent them from being employed for ornamental purposes. *Iceland spar*, so called from the largest and most transparent specimens being found there, is a rhomboidal carbonate of lime, much used for experiments on the double refraction and polarisation of light. *Fluor spar* is a common mineral product, found in many places, but in great beauty and abundance in Derbyshire. It is a fluoride of calcium, occurring in crystals and in nodules of various colours, and often very prettily banded. The nodular specimens are occasionally worked into beads, brooches, and other ornamental purposes; but chiefly manufactured into vases, toilet-boxes, jars, and such-like articles. The acid of fluor spar, when disengaged, is used in etching on glass (FICTILE MANUFACTURES); and the spar itself is occasionally employed, under the blow-pipe, as a flux for promoting the fusion of other minerals.

* *Cameo* (a word of Oriental origin) is the term applied to gems of various colours sculptured in relief. 'The art of engraving on gems,' says Brande, 'boasts of high antiquity, having been practised with various degrees of success by the Egyptians, Greeks, and Romans. It was again revived in Italy in the fifteenth century, and is even at the present day cultivated with great avidity and considerable success. The cameos of the ancients were usually confined to the agate, onyx, and sard, which, on account of the variety of their strata, were better accommodated to a display of the artist's talents; but they are also occasionally found executed on opal, beryl, or emerald, and even on a sort of factitious stone, the *Vitrum obsidianum* of Pliny, distinguished by the moderns as the antique paste. One of the most famous cameos is the onyx at present in Paris, called the *apotheosis of Augustus*. It is one foot in height and ten inches in width.' To this we may add, that a cheap kind of cameo has recently been prepared from large shells found on the coasts of Africa and Brazil. These shells have two layers, the ground being either of a pale coffee colour, or of a reddish orange, and the figure of a nacreous white. Cheap imitation cameos are also extensively manufactured in glass enamel.



Iron-smelting Work.

METALS—METALLURGY.

THE peculiar lustre of the metals—arising out of their opacity and reflective power with regard to light—their conduction of heat and electricity—their density, fusibility, ductility, malleability, and the like, are features which, though differing in each, yet readily distinguish them as a class from all other substances. It is this density and hardness in some, this ductility and malleability in others, and the facility with which many of them can be amalgamated, that have rendered them such valuable aids to human progress, and made them available for almost every purpose of utility or ornament. Without them, indeed, any high degree of civilisation were impossible; they are essential to every process in agriculture, architecture, machinery, navigation—to every art, in fine, which marks the advancement of mankind from the lowest stages of barbarism. As elementary substances, their scientific distinctions have been detailed under CHEMISTRY; we would now direct attention to their history, the localities where found, the modes of obtaining and preparing them, the purposes to which they are applied, their relative values, and other particulars of economic importance.

GEOLOGICAL CONDITIONS.

The metals, as found in nature, are seldom in a state of purity. It is true that the miner occasionally detects a fragment of native metal—pure and ductile as from the crucible of the chemist—but such fragments are rare, and bear no appreciable proportion to the quantity which occurs in the crude state of *ores*. These ores are sulphurets, carbonates, oxides, &c., mingled with earthy impurities, generally situated in veins, sometimes disseminated through rocky masses, rarely in beds or strata, and distributed through the formations of all eras, but more especially through those of the primary and transition series. Thus, iron, the most familiar and useful of all the metals, occurs in more than twenty different mineral states, being combined with carbon, oxygen, sulphur, phosphorus, &c.; is found in veins traversing different formations; is disseminated through various rocks, so as to give to them a ferruginous aspect; and, as clay-ironstone, is interstratified with the clays and shales of the coal-measures. To arrange and classify the ores is the study of the mineralogist; to determine their value, or the amount of metal they contain, is the art of the chemist; to raise them from their various positions, is the labour of the miner; to separate the metal from the earthy impurities with which it is associated, is the work of the metallurgist; and to fashion it into implements, utensils, and machines, is the calling of the founder, blacksmith, machinist, cutler, and others. As with the ores of iron, so with those of the other metals, only that few of them can be said to occur stratified like the clay or carbonaceous ironstone. It must not be supposed, however, that the respective metals always lie in separate veins—that copper, for example, is always the only metal found in a copper vein; or lead in a so-called vein of lead. The fact is, that though some one metal generally predominates, three, four, or even more metals, may be strangely combined and intermixed in the same veinstone. In our own island, the vein which contains lead as the principal metal, often embodies silver, zinc, and cobalt: platinum is generally associated with gold; manganese not unfrequently with iron.

Beds—Veins.

The natural position in which the metalliferous ores generally occur is *veins*, *beds* or *strata*, and *fragmentary deposits*. In the last of these, the ore is associated with sand, gravel, and other superficial débris, which have evidently been transported by alluvial agency from mountain metalliferous districts. The *strata* are for the most part composed of earthy matter, less or more impregnated with one or other of the metals, but it is only those in which the metallic ingredient is peculiarly abundant that demand the attention of the miner. *Veins*, however, are the principal forms in which

metallic ores are distributed throughout the crust of the globe.

A vein may be said to resemble a deep cleft or rent in a clayey field, which has been subjected for some time to the desiccating influences of the sun. This cleft, whatever may be its depth, must of course have a direction underground, either slanting or perpendicular; and if we suppose it filled with metallic ore, we form the idea of a vein, or, as it is termed, a *lode:* if we suppose the cleft filled with a stony substance, we can imagine what is called a non-metalliferous vein or *dike*, of which there are many, sometimes pursuing their own exclusive courses, and at other times intersecting the metalliferous veins. The direction of the lodes is by no means accidental, but nearly determinate. They usually *strike* east and west, and *dip* or underlie either towards the north or south; while the non-metalliferous veins, which run north and south, dip either towards the east or west. The cases in which metalliferous veins assume a north and south direction are few, and chiefly foreign. It frequently happens that the metalliferous lodes, as we have said, cross each other; and, as a leading fact, the intersection of two lodes at a small angle is productive of good ore.

The compositions of the lodes or veins are as variable as the nature of the rocks through which they pass. By far the greater number consist of matter similar to that of the contiguous or intersected rock; but many also contain large intermixtures of quartz. These ingredients for the most part are mingled without regularity or order, and throughout them are dispersed the metallic ores. Sometimes these are aggregated very thickly, and very generally occur in large irregular lumps or patches, called *bunches*, connected with each other by small films or *threads* of ore. On referring to the *known* depths to which different metals extend, it will be found that those which commonly lie near the surface, as lead, zinc, gold, and occasionally tin, do not generally penetrate to any great depth; while those which lie deeper, as copper and silver, are worked in the bottoms of our deepest mines. This arrangement may be the result of a natural law, or it may be apparent, and consequent only upon the limit of our experience and knowledge.

MINING OPERATIONS.

A mine in a complete working condition exhibits a most extensive series of operations, in connection with the shaft, the lifting and descending by ropes and pulleys, the drainage, the excavation, the ventilation, &c. (fig. 1). At the bottom of the shaft, and in the various stages in which the excavations are going on by the miners, in their attempts to follow the lodes, the operations are on a scale which seldom fails to surprise the stranger. When the levels have been carried to a considerable distance from the shaft, the ventilation will be found defective. This deficiency is still further augmented by the increasing number of the men now employed in the works, the presence of a great number of candles and lamps, and the smoke resulting from the larger employment of gunpowder in the process of blasting. The irregular distribution of the metalliferous portions of the lode becomes the cause of inequality in the workings, and renders the sinking of one or more shafts indispensable.

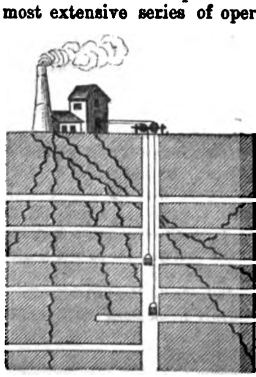


Fig. 1.

When circumstances permit, mines are entered by an adit in a hillside, instead of by shafts. Of this character are the openings into the lead-mines of the north of England, of Derbyshire, and of North Wales, all of which are situated in the carboniferous limestone, and the grits and shales resting upon it. Where the edges of the strata are exposed to view, a spot is selected from which it may be practicable to drive a level upon the vein itself, and in one of the beds known to be favourable to its productiveness. The mining of stratified ores, as the clay or carbonaceous ironstone, is conducted precisely in the same manner as coal.

METALLURGY.

Metallurgy—from the Greek *metallon*, and *ergon*, a work—is the art of separating metals from their ores; and as this separation is undertaken only with a view to some economic purpose, the term may be regarded as embracing the whole art of working in metals, from the reduction of the ore, to the ultimate application of the metallic product. With respect to the primary reduction, though heat be the grand agent, yet so different is the treatment of the different ores as to dressing, roasting, smelting with fluxes, the application of amalgams, and the use of even more complicated chemical processes, that what is peculiar in each, will be best adverted to under our notices of the respective metals, which are here tabulated with their specific gravities, taken at 60° Fahrenheit:

Name.	Specific Gravity.	Melting-Point.	Discoverer.	Date.
Platinum,	21·5	ox. bl.*	Wood,	1741
Gold,	19·5	2016°	Known to the Ancients.	
Tungsten,	17·60	ox. bl.	D'Elhuiart,	1781
Mercury,	13·59	—39°	Known to the Ancients.	
Palladium,	11·55		Wollaston,	1803
Lead,	11·45	600°	Known to the Ancients.	
Silver,	10·5	1873°	" " "	
Bismuth,	9·9	497°	Agricola,	1530
Uranium,	9·0	ox. bl.	Klaproth,	1789
Copper,	8·96	1996°	Known to the Ancients.	
Cadmium,	8·60	442°	Stronmeyer,	1818
Cobalt,	8·9	2810°	Brandt,	1733
Nickel,	8·38	2810°	Cronstedt,	1751
Iron,	7·84	3480°	Known to the Ancients.	
Molybdenum,	8·6	ox. bl.	Hielm,	1782
Tin,	7·283	612°	Known to the Ancients.	
Zinc,	6·89	773°	Paracelsus,	1530
Manganese,	8·01	2800°	Gahn and Scheele,	1774
Antimony,	6·8		Basil Valentine,	1490
Tellurium,	6·26	620°	Müller,	1782
Arsenic,	5·672		Brandt,	1733
Titanium,	5·30	ox. bl.	Gregor,	1791
Aluminum,	2·60		Wöhler,	1828
Magnesium,	1·70		Bussy,	1829
Sodium,	·97	190°	Davy,	1807
Potassium,	·86	136°	" ,	1807
Chromium,	5·9	ox. bl.	Vauquelin,	1797
Columbium,	Undetermined.	"	Hatchett,	1802
Rhodium,		"	Wollaston,	1803
Iridium,		"	Tennant,	1803
Osmium,		"	" ,	1803
Cerium,			Hisinger,	1804
Barium,			Davy,	1807
Strontium,			" ,	1807
Calcium,			" ,	1807
Lithium,			Arfwedson,	1818
Zirconium,			Berzelius,	1824
Glucinium,			Wöhler,	1828
Yttrium,			" ,	1828
Thorium,			Berzelius,	1829
Vanadium,			Sefström,	1830
Lantanium,			Mosander,	1839
Didymium,			" ,	1840
Erbium,			" ,	1840
Terbium,			" ,	1840
Ruthenium,			Klaus,	1844
Niobium,			H. Rose,	1845
Pelopium,			" ,	1846
Norium,			Svanberg,	

Gold.

As the most valuable and longest known of the metals, gold deserves to rank first in our catalogue. When pure, it is of a deep and peculiar yellow colour, rather soft, and extremely heavy, having a specific

* Ox. bl.—Fusible only before the oxy-hydrogen blow-pipe.

gravity of 19·5—that is, nineteen times heavier, bulk for bulk, than pure water. It exceeds all the other metals in ductility and malleability: it may be beaten into leaves 1-282,000th of an inch in thickness, and a single grain may be drawn out into 500 feet of wire. Though soft, its fusing-point is as high as 2016° of Fahrenheit; it is unchanged by fire with access of air—the hottest furnace producing no other effect upon it than to keep it in fusion. It expands during fusion, and contracts in cooling, more than any other metal. It is not acted upon by any of the common acids; but chlorine and a mixture of hydrochloric and nitric acids (*aqua regia*) corrode and dissolve it, forming a chloride of gold, which is soluble in water. The metal occurs in greater or less abundance in almost every quarter of the globe, and is obtained either in the native state, from alluvial sands and gravels, or in mineral veins in combination with silver, and often mixed with metallic sulphurets and arseniurets. In the native state, it occurs in small crystals, in threads or granular fragments, which, when of a certain magnitude, are called by the name of *nuggets*.

The geological formations in which gold occurs are the crystalline primitive rocks, the compact transition strata, the trachytic and trap rocks, and alluvial grounds of the current era. In the three former sources, the ores of the metal are *in situ;* in the latter, it is a travelled or transported product, being carried thither, from the rocks in which it was originally formed, by streams and rivers. In the former case, it is obtained by the difficult and dangerous process of mining; in the latter, the soil or gravel is merely turned over, and the metallic portions—the *gold-dust* of commerce—separated by hand-picking, washings, and siftings. It is thus obtained from *mines* in Brazil, Peru, Mexico, Hungary, Transylvania, and the Uralian Mountains; and from *sands* from the Peruvian, Mexican, and Brazilian rivers, the coast of California, several of the rivers of Africa, from the Rhine, Rhone, and Danube, in continental Europe, and in small quantities from Wicklow in Ireland, from Cornwall, and from the Leadhill district in Scotland. The great sources of gold at the present day (1857) are the alluvial plains of California and Australia. The latter country seems to possess an inexhaustible supply of this precious metal. With the exception of iron, perhaps there is no metal more generally disseminated than gold; but in comparatively few localities is it sufficiently abundant to repay the cost of mining and collecting. The deposits, for example, in our own country are quite insignificant; that of Wicklow, to be sure, yielded some years ago a few thousand ounces, but is now, we believe, abandoned like all the other localities.

The following is the treatment of the gold ore as practised at one of the most extensive mines in Brazil: The ore is first removed from its bed by blasting, and is afterwards broken by female slaves into small pieces, about the size of the stones put upon macadamised roads; after which it is conveyed to the stamping-machine, to be reduced to powder. This machine consists of a number of perpendicular shafts placed in a row, and heavily loaded below with large blocks of iron; these, being alternately lifted up to a certain height by a toothed cylinder, turned by a large water-wheel, fall down upon and crush the stones to powder. A small stream of water, constantly made to run through them, carries away the pulverised matter to what is called the *strakes*, a wooden platform, slightly inclined, and divided into a number of very shallow compartments, of fourteen inches in width, the length being about twenty-six feet. The floor of each of these compartments is covered with pieces of tanned hide, about three feet long and sixteen inches wide, which have the hair on; the particles of gold are deposited among the hairs, while the earthy matter, being lighter, is washed away. The greater part of the gold-dust is collected on the three upper skins, which are changed every four hours; while the lower skins are changed every six or eight hours, according to the richness of the ore. The sand which is washed from the head skins is collected and amalgamated with quicksilver in barrels; while that from the lower skins is conveyed to the washing-house, and concentrated over strakes of similar construction to those of the stamping-mill, till it be rich enough to be amalgamated with that from the head skins. The barrels into which this rich sand is put, together with the quicksilver, are turned by water, and the process of amalgamation is generally completed in the course of forty-eight hours. When taken out, the amalgam is separated from the earthy sand by washing; it is then pressed in chamois skins, and the quicksilver is separated from the gold by sublimation. In different countries, various metallurgic processes are adopted; but, on the whole, that of stamping and amalgamating seems to be the readiest and most successful. The metallic grains found in the sands of rivers do not require to be subjected to any metallurgic process, in the strict acceptation of that term.

The applications of gold are numerous and important; but in most cases it is used in an alloyed, and not in a pure state. This arises from its softness, and consequent liability to be worn down; the common alloys of copper or silver conferring the necessary hardness, without impairing in any appreciable degree the beauty and lustre of the more precious metal. In this condition it is employed for coin, plate, and a variety of articles of luxury and ornament, for which purposes it has ever been in the highest repute. It is also extensively used in the arts for gilding, conferring on materials often the most worthless the semblance of its own unrivalled beauty. The gold coin of the realm, commonly called *standard gold*, consists of 11 parts pure gold and 1 of copper; it is extremely ductile and malleable, but harder than pure gold, and therefore better calculated to resist the wear and tear of circulation. The colour of this alloy is deeper yellow than that of pure gold, and verges upon orange; 20 pounds troy of it are coined into $934\frac{1}{2}$ sovereigns; 1 pound troy, therefore, produces $46\frac{29}{40}$ sovereigns. It sometimes happens that a part of the alloy of gold coin is silver; hence the pale colour of some sovereigns as compared with others. The gold employed by jewellers, &c., is all less or more alloyed; and from the great skill now attained in putting rich surfaces on such alloys, it requires very considerable skill on the part of the purchaser to prevent deception. The art of *gilding* consists in covering other substances with a thin coat of gold, which may be done either by mechanical or chemical means. The mechanical mode is the application of gold-leaf or gold-powder, which is made to adhere by size or varnish; the chemical, by plunging the substances in solutions of gold, or by the electrotype process. The production of *gold-leaf* and *gold-wire* of such extreme fineness as we have mentioned, requires considerable ingenuity; and is all the more readily accomplished the finer the standard of the metal. The former is made by rolling out plates of pure gold as thin as possible, and then beating them between folds of fine vellum—gold-beaters' skin—by a heavy hammer, until the requisite degree of tenuity has been reached; the latter is formed by drawing a cylindrical rod of the pure metal through a series of gradually decreasing holes punched in a steel plate.

Silver.

This is another of the metals which have been longest known and esteemed, having been extensively employed from the earliest times in the fabrication of articles both of utility and ornament. Every one must be familiar with its peculiar white colour and great lustre; the epithet *silvery* conveying an idea not to be confounded with any other. In malleability and ductility, it ranks next to gold, being frequently hammered into

leaves 1-10,000th part of an inch in thickness, and drawn into wires finer than the human hair. Its specific gravity is only 10·5, and its fusing-point 1873° of Fahrenheit. Silver is a widely disseminated product of nature, occurring in the metallic or *native* state in fine threads or strings in various rocks, but chiefly in veins in primitive and secondary mountains. It is found also in combination with other metallic ores, as those of lead, and as a native sulphuret.

Silver, we have said, is very generally distributed; but the great sources of supply are Mexico and Peru in the New World. A considerable supply is also obtained from other parts of South America, from the Uralian Mountains, Austria, and Norway. In Britain, it is found in small quantities, associated with lead—as in Derbyshire, at Alston Moor, Leadhills, &c.; and also in veins in the island of Anglesey. Most of the silver-mines are situated in high, bleak, desolate tracts, which would never be inhabited by man, unless for the sake of the treasures in the rocks beneath. Those of Peru, for example, are found at an elevation of from 12,000 to 14,000 feet above the sea, in a wild barren region, to which every necessary of life has to be brought from a toilsome and expensive distance; and yet towns like Cerro de Pasco, of 18,000 inhabitants, have there risen into life and activity. The silver veins of Pasco are extremely rich. One of them has already been traced to the length of 9600 feet, and the breadth of 412 feet; another is known to the extent of 6400 feet long, and 380 feet in breadth. From these large veins, numberless smaller ones branch off in various directions, so that a net-work of silver may be supposed to spread beneath the surface of the earth. Some thousand openings, or *mouths*, are the entrances to these mines. Most of these entrances are within the city itself, in small houses; and some are in the dwellings of the mine-owners. All are worked in a very disorderly and careless way, the grand object of their owners being to avoid expense. All the other operations, it would appear, are as rude as the mining: the raising of the ore, the breaking and stamping, the separating of the silver from the dross, are all executed in a very clumsy, imperfect, and at the same time a very expensive manner. 'The amalgamation of the quicksilver with the metal is effected by the tramping of horses! The animals employed in this way are a small ill-looking race, brought from Ayacucho and Cuzco, where they are found in numerous herds. The quicksilver speedily has a fatal effect on their hoofs, and after a few years the animals become unfit for work. The separation of the metals is managed with as little judgment as the amalgamation, and the waste of quicksilver is enormous. It is computed that on each mark of silver, half a pound of quicksilver is expended. The quicksilver, with the exception of some little brought from Idria and Huancavelica, comes from Spain in iron jars, each containing about seventy-five pounds' weight of metal. In Lima, the price of these jars is from 60 to 100 dollars each, but they are occasionally sold as high as 135 or 140 dollars.

The numerous uses and applications of silver are well known. In its pure state, it is too soft for coin, plate, and most ornamental purposes; but alloyed with copper in proper proportions, it becomes hard, without being materially impaired in colour. The *standard silver* of British coin is an alloy of 11 ounces 2 pennyweights of pure silver, and 18 pennyweights of copper, to the pound troy; and this weight is coined into sixty-six shillings. In the arts, silver is extensively used, particularly for silvering or plating other metals; and for this purpose, silver-leaf and solutions of silver are applied much in the same way as in gilding. The oxide of silver is used for colouring porcelain; and several of its salts are now largely employed as the principal agent in preparing photographic portraits. The only pure acids which dissolve silver are the nitric and sulphuric, producing respectively nitrate and sulphate of silver. The nitrate, for example, is the strongest and most manageable caustic known in surgery, being applied as a common black wash, or as *lunar caustic*, which is merely the nitrate melted and run into moulds after evaporation. A solution of two drachms of the nitrate of silver in an ounce of water, coloured by a little sap green or Indian ink, forms the marking-ink of the laundress; and when a solution of nitrate of silver is mixed with alcohol, a violent effervescence ensues, and *fulminating powder* is produced. This powder is one of the most dangerous compounds known, exploding with violence upon the slightest friction, or when struck, rubbed, or heated.

Copper.

This was one of the earliest known of the metals, and not less extensively used than known by the nations of antiquity; its tenacity and durability rendering it the best substitute for iron, ere man had learned to reduce that valuable but more refractory metal. It derives its name from the island of Cyprus, where it was extensively mined and smelted by the Greeks, who employed it either pure, or in an alloyed state (bronze), in the fabrication of their domestic utensils and implements of war. It is a metal of a beautiful red colour, and considerable lustre, very malleable and ductile, but more capable of being hammered into leaves than drawn into wire. In tenacity, it yields to iron, but surpasses gold, silver, and platinum—a wire of only $\frac{1}{10}$th of an inch being strong enough to support a weight of 300 pounds. Its specific gravity is 8·96, and its fusing-point, 1996° Fahrenheit—that is, nearly a white heat. It is found occasionally in a native state in films, strings, or amorphous masses, but in no considerable quantity. The most remarkable masses of native copper hitherto discovered are said to be one in Brazil, which weighed about 2620 pounds; another in the bed of a stream to the south of Lake Superior, which measured not less than fifteen feet in circumference; and a third in Australia, which was exhibited at a festal inauguration of a mining company in Adelaide. The great source of the commercial supply is, as in the case of the other metals, from ores, of which the most productive is copper pyrites—that is, copper in certain combinations with sulphur and other metallic impurities. In this state it is found in almost every mineral district in beds—as the *kupfer-schiefer*, or copper-slate, of Germany—but more commonly in veins in primitive and secondary mountains. A less abundant ore of copper is the carbonate of copper, which often occurs associated with the copper pyrites. Copper-mines are largely worked in England, Chile, Cuba, Germany, Sweden, and Siberia; less extensively in France, Spain, Hungary, and Norway; and recently, with great success, and still greater promise, on the shores of Lake Superior, and in Australia.

The English mines are chiefly situated in Cornwall, where the most common ore consists of copper, iron, and sulphur, in nearly equal proportions, and is called yellow copper ore, or copper pyrites; veins are also worked in the counties of Devon, Anglesey, and Stafford. Owing to the want of fuel in Cornwall and Devon, the ores, after being dressed—that is, ground and sifted—are shipped from these counties to South Wales, to be calcined and smelted, principally to works situated on the navigable rivers of Swansea and Neath; the smaller quantity of material being thus carried to the greater, while the vessels load back with coal for the use of the mining steam-engines. The reduction of the ore is a tedious and complex process. 'It is first roasted in a reverberatory furnace (fig. 2), by

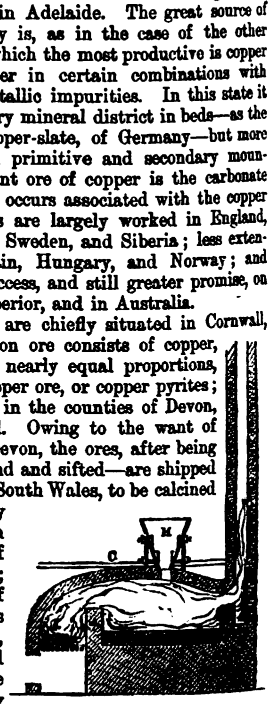


Fig. 2.

which much of the sulphuret of iron is converted into oxide, while the sulphuret of copper remains unaltered. The product of this operation is then strongly heated with silicious sand; the latter combines with the oxide of iron to a fusible *slag*, and separates from the heavier copper compound. When the iron has, by a repetition of these processes, been got rid of, the sulphuret of copper begins to decompose in the flame-furnace, losing its sulphur, and absorbing oxygen; the temperature is then raised sufficiently to reduce the oxide thus produced by the aid of carbonaceous matter. The last part of the operation consists in thrusting into the melted metal a pole of birch-wood, the object of which is probably to reduce a little remaining oxide by the combustible gases thus generated.' The quantity of copper yielded by the ore is commonly about eight or nine per cent.; and the fuel consumed ranges from fifteen to eighteen parts for every part of metal produced.

The quantity of copper mined in Britain in 1820 amounted to 8127 tons; now it is considerably more than double that quantity, and valued at little short of £2,000,000. This supply is more than sufficient for the demand of the United Kingdom; hence considerable shipments in pigs, sheets, nails, wires, &c., are made to the East Indies, China, United States, West Indies, Brazil, Canada, and Holland. Besides the produce of British mines, considerable quantities of ore have of late been imported from Chile, Cuba, and especially from Australia.

The uses of copper are numerous and highly important, the metal ranking next to iron in real commercial value. It is used, as is well known, for coin, for sheeting or sheathing the bottoms of vessels, for boilers, and a great variety of implements and utensils; in the manufacture of blue and green colours; and in medicine. Alloyed with zinc, it forms *brass* and *pinchbeck*—the former containing from 28 to 34 per cent. of zinc. In the formation of brass, the zinc may either be added directly to the melted copper, or granulated copper may be heated with calamine and charcoal-powder. *Gun-metal*, a strong and valuable alloy, consists of 90 parts copper and 10 of tin; *bell* and *speculum metal* contain a much larger proportion of tin, and are consequently brittle and less durable. A good *bronze* for statues is made of 91 parts copper, 2 parts tin, 6 parts zinc, and 1 part lead. The bronze of the ancients was an alloy of copper and tin; and the *argentane* or German silver of the moderns is a compound of copper, tin, and nickel. *Ormolu* is the name given to a particular alloy of 52 parts zinc and 48 copper; and the *Biddery-ware* of India—so called from a town of that name—is a compound of copper, lead, tin, and zinc, rendered black by immersion in a solution of sal-ammoniac, saltpetre, common salt, and blue vitriol. All these alloys are of infinite use, entering into the fabrication of almost every species of machinery, implement, utensil, and ornament—from the drawing, pointing, and heading of a pin, or the stamping of a button, to the casting of a statue, or the founding of a ponderous field-piece. Though thus vieing with iron in its applicability to the purposes of civilised life, its salts and solutions are highly poisonous; hence the frequent evils arising from the use of neglected or ill-cleaned culinary utensils of copper. Water containing copper in solution is changed into a bright blue by the addition of a little hartshorn or liquid ammonia; and into a ruddy brown on the addition of yellow prussiate of potash. On immersing a piece of polished steel in any liquid containing copper, the surface will soon become coated with a film of the latter metal.

What is called *bronzing* is a method of colouring wood, iron, plaster of Paris, or other material, so as to imitate bronze, but which has, in reality, little connection with that alloy. The process is thus indicated in Webster's *Cyclopædia*: 'First, the article is to be painted of a dark colour, such as bronze acquires when it has been very long exposed to the air, or when buried underground. This colour is produced by grinding a mixture of Prussian blue, verditer—a precipitate of oxide of copper with lime—and spruce ochre in oil. What is called *bronze-powder*, sold in the shops, is now to be applied, just before the oil-paint is quite dry, to the prominent parts, where the metal is supposed to have acquired some lustre by being rubbed against. The bronze-powder may be laid on by a ball of cotton-wool, or in a similar manner.' Bronzing thus effected is now much in request; it has the advantage of wearing well, keeping clean, and giving effect to other colours. *Lacquering* is a somewhat allied process, and consists in applying a peculiar varnish either to brass-work, to prevent its tarnishing, or to give tin and articles covered with silver-leaf the appearance of brass. The ingredients of such a varnish are wholly non-metallic, consisting chiefly of turmeric, anotta, saffron, gum-lac, amber, and the like, dissolved in alcohol.

Iron.

This truly precious metal is capable of being cast into moulds of any form; of being drawn out into wires of any desired strength or fineness; of being extended into plates or sheets; of being bent in every direction; of being sharpened, hardened, and softened at pleasure. Iron accommodates itself to all our wants, our desires, and even caprices; it is equally serviceable in the arts, the sciences, agriculture, and war. The same ore furnishes the sword, the ploughshare, the scythe, the pruning-hook, the needle, the graver, the spring of a watch or of a carriage, the chisel, the chain, the anchor, the compass, the cannon, and the bomb. It is a medicine of much virtue, and the only metal friendly to the human frame. The ores of iron are scattered over the crust of the globe with a beneficent profusion, proportioned to the utility of the metal; they are found under every latitude and zone, and in every geological formation.

The forms in which the metal is commonly found in the arts are *crude* or *cast iron; malleable* or *wrought iron;* and *steel.* Neither of these commercial varieties is pure, as they contain more or less carbon, silicium, sulphur, and phosphorus.

The preparation of pure iron takes place only in the chemical laboratory. One method is to introduce into a Hessian crucible four parts of fine iron-wire clippings, and one part black oxide of iron; cover these with powdered hard white glass—a mixture of white sand, lime, and carbonate of potash—and raise to a bright white heat. The oxygen present in the oxide of iron burns away the carbon, &c., in the iron of the wire, and on cooling, a button of pure metallic iron is found in the bottom of the crucible. Another process is to place some red oxide of iron in a porcelain or hard glass tube, raise to a low red heat, and pass a stream of hydrogen through the tube. The hydrogen abstracts the oxygen from the peroxide of iron, forming with it water-vapour, which is carried out of the tube by the rush of gas, whilst pure iron remains behind as a grayish-black powder. In this latter condition, the metal is used in medicine. The former process yields the metal in mass, in which form its properties can be best studied.

Pure iron has a bluish-gray colour, and strong metallic lustre, which is heightened by polishing. It has a specific gravity of 7·84, and is one of the most infusible of metals, requiring the highest heat of a smith's forge to liquefy it. When beaten out under the hammer, it exhibits a granular structure; but when passed repeatedly between rollers, it assumes a fibrous texture in the direction of the length. This fibrous character is best seen in ordinary malleable or bar iron, which is almost pure; and the great difference in the comparative strength of *bar* over *cast* iron depends on this property. The axles of railway carriages are most carefully prepared from iron which has been rolled and re-rolled till the fibrous appearance is

at a maximum; but, unfortunately, such precautions are unavailing, as true fibrous iron, after much wear and tear, especially when repeatedly strained or jolted, gradually loses its thread-like structure, and becomes crystalline and brittle. This alteration in the arrangement of the physical atoms of the iron of axles, doubtless occasions many serious accidents on our railways.

When raised to a red heat, iron admits of being hammered into any form; and subjected to a white heat, two pieces of this metal may be readily and completely joined together. This operation is called *welding*, and no metal can surpass iron in its readiness of being manipulated in this manner. It is powerfully attracted by the magnet, and at the same time becomes magnetic; but it loses this property the moment the magnet is withdrawn. Steel, however, may be rendered permanently magnetic by being rubbed over with a magnet. When exposed to air and moisture, iron absorbs oxygen, and passes into *peroxide* or *red oxide of iron*, in other words, *rust*.

Metallic iron is seldom found native. In Connecticut, a vein of iron was found two inches thick, and capable of being wrought into nails by the blacksmith. In Germany and France, smaller pieces have been found; and very thin plates or scales are disseminated through rocks of the basalt, gneiss, and mica-schist character.

Meteoric iron is more abundant: large masses of ignited matter have been observed to fall from the atmosphere on the earth's surface, and other metallic masses have been found in situations which leave no doubt of their having been placed there under similar circumstances. In 1803, a shower of meteoric stones, about 3000 in number, fell at L'Aigle, in Normandy, some of which weighed seventeen pounds each; and other masses have been observed to fall, or have been found, at Braunau in Bohemia, at Harmony Creek in North Carolina, at Atacama in South America, in Brazil, and in Siberia. These meteoric masses are of two kinds: at times they consist mainly of metallic iron in a massive condition, but perforated with many holes filled with stony matter, which gives the metallic portion a branched appearance; whilst occasionally they are essentially of a rocky consistence, in which the iron is imbedded in grains or small pieces. Meteoric iron is good to work, and it is probable the original Damascus blades were made from this material. The Emperor Alexander I. of Russia had a sword made from such iron, which was so pliable that it could almost be bent in two; and the Esquimaux were found in possession of knives, &c., which had been fabricated therefrom. The swords of the caliphs, as related by the Arabian poets, were forged from meteoric or *heaven-descended* iron, and are described as 'glancing like a lightning flash, cutting through marrow and bone; he who wields it has all before him; steel and precious stones vanish like water before its brilliancy.'

Though rarely found as a metal, iron is abundantly and widely distributed in other conditions. All spring and river waters contain more or less iron in solution, and in some the quantity is so great, that an ochrey deposit takes place on the stones over which the water flows, or in the lakes into which the ochrey springs enter. All soils contain iron, to which they owe their red or rusty aspect, and the majority of stones are composed in part of this metal. A compound of sulphur and iron, called iron pyrites, occurs in roofing-slates and elsewhere; but the quantity of iron so distributed, though considerable, is not available for the manufacture of the metal, as the sulphur associated with it renders it objectionable.

The main sources of iron in this country are the *red-iron ore* or *hæmatite*, and the *black-band ironstone*. The former is found largely in Cornwall and Cumberland, and constitutes the principal English ore. It is generally obtained in a compact state, often fibrous in structure, and sometimes presents, externally, a nodular, kidney, or reniform appearance. When mixed with clay, it constitutes *red ochre*. The black-band ironstone is the ore generally worked in Scotland. It occurs in great abundance in a broad belt which stretches across Scotland, the central line and direction of which is represented by the firths of Forth and Clyde. It is found in layers or strata, some distance below the surface of the ground, and interlayered with coal and limestone. On the continent, in Norway, Sweden, &c., as likewise in Elba and the United States, a third ore of iron is found—namely, the *magnetic-iron ore* or *loadstone*. In this condition, iron is found in such quantity, that it forms small hills, which are powerfully magnetic.

In the manufacture of iron from the black-band ironstone, the first operation is that of roasting the ore. This consists in throwing the blocks of ironstone, as they are brought up the pit-shaft, out on an adjoining field, and setting fire to them. Generally, the ironstone contains so much coaly matter, that when once ignited, it continues to burn of itself. The combustion must proceed slowly; and accordingly it is customary to cover the burning mass with clay or rubbish, to serve as a damper in excluding much air. Were the burning allowed to go on quickly, and the temperature of the mass thus rise high, an iron glass would be formed, from which the after separation of the iron is extremely difficult. Generally, the size of the ironstone hill is such, and the combustion allowed to proceed so slowly, that six weeks are occupied in the burning process, and other six weeks elapse before the red-hot mass has sufficiently cooled down to admit of the workmen pulling it to pieces. The object in roasting the black-band ironstone is to get rid of useless and deleterious matters. The original ore is considered a rich one if it contain one-third of its weight of metallic iron, and the remaining two-thirds of other matters. The true composition of such ores will be best observed from the following

Analyses of Black-band Ironstones.

	I.	II.
Carbonate of iron,	83·52	62·06
Organic (coaly) matter,	13·59	16·23
Carbonate of lime,	0·58	15·36
Carbonate of magnesia,	0·04	0·68
Alumina,	0·31	0·07
Sulphur,	traces.	
Silica,	1·96	5·60
	100·00	100·00
100 parts of the above ironstones contain of metallic iron	40·32	29·93
100 parts of the above ironstones will yield of roasted ore	59·89	59·39
100 parts of the roasted ore will afford of metallic iron	67·32	54·29

The roasting of the ore very much simplifies matters, as what is left as roasted ore consists mainly of iron, oxygen, and a little sand. The same ingredients constitute the red-iron ore or hæmatite; so that in describing the after-parts of the process for the extraction of iron from its ores, the chemical changes referred to as undergone by the roasted iron ore of Scotland, are exactly similar to those which take place during the working-up of the red-iron ore of England.

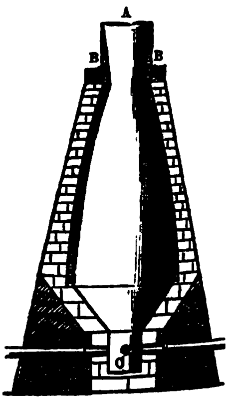


Fig. 3.

The process of extracting the iron from the roasted ore is conducted in a blast-furnace (fig. 3). In external form, it somewhat resembles a sugar-loaf, with

the apex knocked off. Great care must be taken in the construction of the furnace, which is lined with fire-brick in the interior. At the upper part, A, there is an opening for the escape of gases, near which, B, are side-doors, for the introduction of the ore, fuel, &c. At the lower part, there is the crucible, C, as also the pipes or *tuyères*, *b*, *b*, for the passage of air into the furnace. The materials introduced into the furnace are coal, roasted ore, and lime. The coal must be as free from sulphur as possible, and the lime should contain a mere trace of silica, sulphur, and phosphorus. The proportions of coal, iron ore, and lime vary according to their several degrees of purity; but the average amount of each may be observed from the following table, taken from the working journal of a large ironwork:

	Cwt.	Qrs.	Lbs.
Coal,	8	0	0
Roasted ore,	6	2	0
Red ore,	0	2	0
Lime,	2	2	14

The above quantities are thrown into the furnace as nearly as possible at the same time, and constitute one charge. The coal is placed on one wagon, and the ore (*burden*) and lime on a second; and both being raised to the top of the furnace, have their contents discharged therein (fig. 4). The number of such charges thrown

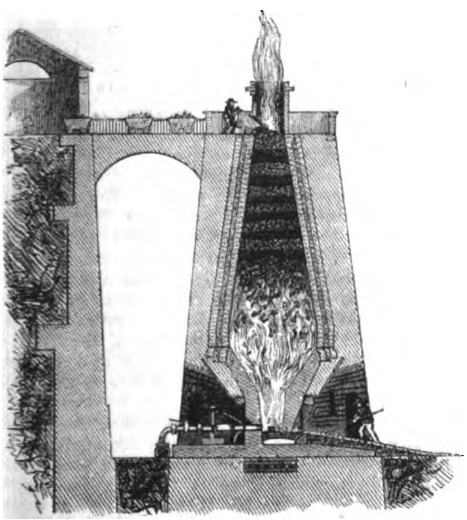


Fig. 4.

into the furnace every twelve hours is about sixty. The feeding-time is from six o'clock in the morning till six at night, and 6 P.M. till 6 A.M. Now, to understand aright the chemical changes undergone by the materials introduced into the furnace, it must be remembered that the iron ore consists of iron, oxygen, and sand, and that the great object of the iron-smelter is to separate the two latter substances from the former. The coal introduced has two functions to fulfil: in part it is burned so as to raise the contents of the furnace to that high temperature that they will be enabled to act on each other; and in other part, it carries away the oxygen which was originally in combination with the iron in the roasted ore. The lime plays the part of a flux, and combines with the sandy matter to form a slag. During the whole operation, hot air is being constantly forced in at the lower part of the furnace, so as to aid in the necessary combustion. The roasted iron ore being thus deprived of its oxygen by the coal, and its sand by the lime, allows the other constituent, the iron, to trickle down through the mass of red-hot cinders to the lower part or hearth of the furnace. The slag produced by the combination of the sand and the lime likewise runs down to the hearth, and there floats on the surface of the molten iron. At intervals, the furnace is worked at the lower part by the introduction of long iron rods, which are moved from side to side; and the slag as it accumulates is allowed to run off. Previous to the *tapping* of the furnace, an arrangement is made to receive the molten iron. Immediately in front of the furnace, a quantity of damp sand is laid, in which a number of little canals or gutters are formed. The larger gutters, called the *sows*, have smaller ones branching off from them, which are termed the *pigs*. At six A.M., or six P.M., everything being in readiness, the blast of air is shut off, the furnace tapped by driving an iron rod through the stopper of hardened clay; and the molten iron runs first into the main sow, then into the lateral sows, and from these into the pigs. When the iron ceases to flow from the furnace, the opening is plugged up by a new stopper of damp clay, the blast set on, and the operation goes on again for the next twelve hours. The working-parts of an iron-smelting work consist, therefore (see Frontispiece), of A, *the receiver*, an arrangement for retaining the compressed air; B, *the heaters*, consisting of an oven, through which the *cold blast* is sent to make it the *hot blast;* C, the smelting-furnace, into which the roasted ore, coal, and lime are thrown, and where the iron is separated from the other ingredients; D, a series of gutters to receive the molten iron; E, an inclined plane to run off the slag; and F, adjoining ground for piling up and storing the bars of iron (*pigs*).

The constituents of pig or cast iron are 95 to 97 per cent. of pure iron, 3 to 5 per cent. of carbon, with minute quantities of sulphur, phosphorus, and silicon. In commerce, the pig-iron is rated No. 1, 2, 3, and 4, according to the quantity of carbon present. No. 1 pig-iron contains most carbon, and is more fusible than the others, hence it is generally preferred for castings, and commands the highest price. No. 4 contains least carbon, is much less fusible, and is principally employed by the worker in malleable iron. Nos. 1 and 2 are often styled *gray iron*, and Nos. 3 and 4, *white iron*. A good workman, who is accustomed to see the white hot metal run off from the blast-furnace, at once knows what quality of iron he will obtain when the molten mass cools.

The iron blast-furnace will be best understood if it is likened to the stomach of an animal. Both are the receptacles of heterogeneous substances, and each in its own way separates the good material from the bad. Both are liable to derangement. If much sand is present in the iron ore or the lime, this serves as the counterpart of bad food, and the furnace suffers from indigestion; and when once wrong, it is difficult to get right again, without the administration of physic, which in the case of the blast-furnace is a liberal dose of good lime.

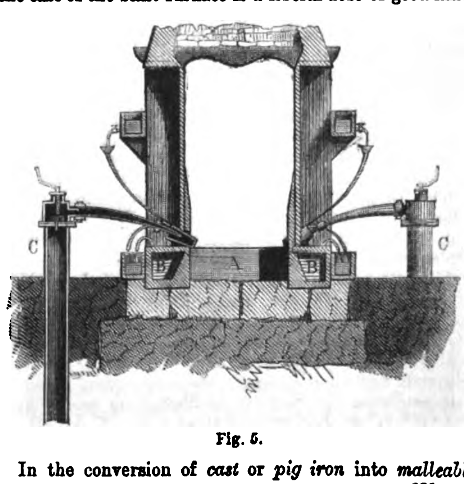


Fig. 5.

In the conversion of *cast* or *pig iron* into *malleable*

or *bar iron*, endeavours are made to retain all the iron, and to get rid of the other substances. This is accomplished by several operations. The pig-iron is first introduced into the *finery* furnace (fig. 5), on the hearth of which, A, much fuel is burning. The lower part of this furnace consists of plates of iron riveted together, and covered with loam or clay in the interior. To keep the sides of the furnace from becoming overheated, a stream of water, B, is constantly circulating round the iron plates; and to aid the rapid combustion of the fuel, hot air is driven in under great pressure from six jets or tuyères, C, C, ranged at the sides of the furnace. When the heat is great, the iron melts, some of its impurities are driven away, and the half-purified iron is run into a shallow trough, where it cools, and solidifies into a plate of *fine metal*, about two inches in thickness. After having undergone the *refinery* operation, the iron is introduced into a *puddling* or *reverberatory* furnace (fig. 6), on

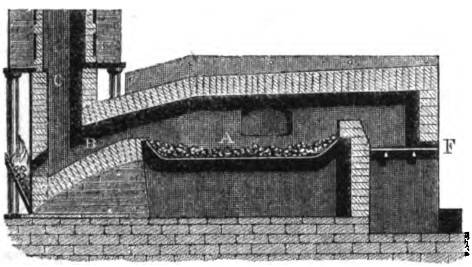


Fig. 6.

the hearth, A, of which the iron plate of fine metal, broken in pieces, is placed. In this part of the process, the fuel is not mixed with the iron, but is kept separate therefrom, and is consumed on an ordinary fire-grating, F, at the one end of the furnace. When the coals are being burned, the heat and combustible gases evolved are carried over the surface of the iron lying on the hearth, A, thence by a contracted passage, B, to the chimney, C. The result is, that the plates of iron rapidly fuse; and the hot air, as it impinges on the molten iron, combines with the impurities contained therein, and for the most part removes them. This is accomplished by the oxygen of the air (1) seizing the carbon and carrying it off as gaseous carbonic acid; (2), combining with the sulphur, and volatilising it as sulphurous acid, and uniting with the phosphorus and silicon to form phosphoric and silicic acids, which are in greater part left behind in the slag. After two to three hours' stirring or agitating, the impurities are separated, and the iron, now much less fusible, assumes a granular state, in which condition it is rolled into large balls. These balls are carried, whilst still hot, to the *forge-hammer* or *steam-hammer*, where they are repeatedly and suddenly compressed by an enormous weight, which squeezes out the remaining impurities, like water from a sponge, and leaves the pure iron. The latter is conveyed at once to a series of grooved rollers, in passing through and through which, it is rolled and re-rolled; its particles are thus compacted, and its tenacity greatly increased. By these several processes, the metal is converted from a fusible, hard, and brittle substance, to a tough and elastic bar, which is hardly fusible; and which, from its property of yielding and altering its form under the hammer, has acquired the name of *malleable* iron. There are various qualities of malleable iron, according to the processes followed; and what is strange, the most perfect processes will not bring the iron of one district up to the same standard as another, nor will the forging of one season be equal, even from the same furnace, to the forgings of another season.

At the present time (1856–7), the iron world has been startled by the announcement of a new and rapid process of purifying *cast* or *pig iron*, and obtaining therefrom *bar* or *malleable* iron, and *steel*. The patentee, Mr Bessemer, takes the liquid iron as it flows from the blast-furnace, receives it in a large covered ladle, (fig. 7), made of malleable iron, lined with loam or clay, and inserts in the molten mass a fire-clay pipe, through which air is driven with great force. The hot blast is preferred to the cold blast, but the latter will do. The oxygen of the air, as it gurgles through the molten iron, combines with the carbon and other impurities, and carries these rapidly away. The ladle being tilted round, the half-purified iron is then allowed to flow into a shallow iron trough,

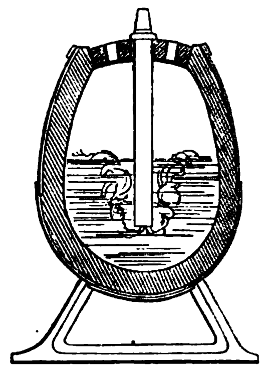


Fig. 7.

where it cools and becomes *fine metal*. This part of the operation is the equivalent of the ordinary *finery furnace*. The plate of fine metal is broken in pieces, and introduced into a *reverberatory* or *puddling furnace*, somewhat similar in shape to that ordinarily employed, but pierced with a number of openings at each side, through which fire-clay nozzles are inserted, and air —hot or cold—driven into or upon the iron, when it becomes molten. Steam is likewise introduced, especially at the commencement of the process. The air being thus brought intimately in contact with the half-purified iron, the remaining impurities are rapidly carried away. Where great purity is required, Bessemer recommends that the spent gases from the fire-grate of the puddling-furnace, which often contain sulphurous acid, should not be allowed to come in contact with the iron; and to obviate this contamination, the iron is enclosed in retorts similar to those used at a gaswork, and the air forced through the molten metal when enclosed in such.

More lately, Bessemer has suggested that the process of refining pig or crude iron should be accomplished by a single operation. For this purpose, an air-furnace is employed, in which there is placed a fire-clay or black-lead crucible, capable of holding, when three-fourths full, about seven hundredweights of molten iron. Prior to the introduction of the metal, the crucible is surrounded by fuel; and when the vessel has attained a bright-red heat, the iron is run in by a funnel inserted at the upper part of the crucible, and thereafter the tube conveying the blast is thrust in. The air, or air and steam, act on the impure iron. The free oxygen carries off the carbon as carbonic acid, and the water acting upon the iron, is decomposed; the hydrogen thereof is set free, and the oxygen combining with the iron, forms oxide of iron, which is itself decomposed by the carbon uniting with the oxygen to form carbonic oxide, and liberating the iron in the metallic condition. Besides the changes enumerated, a large amount of iron is converted into oxide of iron by the excess of oxygen thrust in. The sulphur present as impurity is burned partly away as sulphurous acid, by uniting with the oxygen of the air, and in other part is acted on by the hydrogen derived from the steam, and carried off as sulphuretted hydrogen. The phosphorus is oxidised into phosphoric acid, and in greater part is left still in the iron. After the blast has been on for fifteen or twenty minutes, the jets of flame which issue from the molten mass elongate very much, and continue so for five or six minutes, when they

subside by degrees, till they almost cease; and in thirty-five minutes from the commencement, the process is complete. During the progress of the operation, a copious discharge of slag takes place, which mostly remains as a scum on the surface of the pure iron which forms the denser and lower stratum. The tap-hole in the crucible being unstopped by driving an iron rod into the clay-stopper, the liquid iron is run into a mould or founder's ladle. For castings which require much carbon in the iron, Bessemer first refines the iron by the above operation, and then thrusts into the molten mass some wood, bituminous shale, carbonaceous matters in general, or a stream of carburetted hydrogen, till the requisite amount of carbon is obtained. Bessemer likewise lays claim to the introduction of dry carbonate of soda, and dry carbonate of potash into the molten iron by means of the air-blast, whereby the silica is more easily removed, and a slag formed.

Theoretically, the process of Bessemer is a correct one. By the older and ordinary methods, the air tardily assisted in carrying off the impurities, because it was only sparingly admitted to the iron; but without altering the agent which accomplishes the purification, he expedites the process by thrusting air in great abundance through the impure iron. Practically, however, it does not as yet seem possible by Bessemer's process to burn away the impurities, without at the same time oxidising, burning, or wasting much good iron. It appears highly probable that the great practical skill of our ironmasters will be found sufficient to surmount this difficulty, and a method be adopted whereby the admission of air in minimum quantity be so regulated, that, whilst it burns away the impurities, it will not be allowed to proceed so far as to burn the iron itself. The present system of *refining* and *puddling* iron is notoriously a primitive, time-devouring, and stationary one; and any inquiry having reference to the shortening of the number of hours required, must be of advantage at all times. The process of Bessemer is far from being a perfect one, but it is a step in the right direction, which will doubtless be carried further; and Bessemer ought to receive the thanks of the *iron world* for having given impetus to thought on the subject, which was very much wanted, and which will undoubtedly, in the hands of some one, lead to most important practical and commercial results.

Steel.—Bar-iron is converted into steel by being exposed to the action of heat in contact with carbonaceous matter. Steel is thus a peculiar stage of iron, depending on the quantity of carbon which it contains, though we are unable to give a criterion for that quantity. Pig-iron contains more carbon than steel, and steel about one per cent. more than wrought iron. Steel is therefore an intermediate step in the transition of pig to wrought iron. It has consequently been produced by melting these substances together; by which means the pig-iron has imparted to the wrought iron so much of its carbon as would serve to reduce it to a kind of steel. There are three kinds of steel: blistered steel, shear steel, and cast steel. *Blistered steel* is made by placing alternate layers of wrought iron and carbon in a furnace exposed to considerable heat. The steel thus made is found to contain small bubbles or blisters, and the process is termed *conversion* or *cementation. Shear steel* is made by choosing proper pieces of blistered steel, about 3 feet long, and 1½ inch square. Half-a-dozen of these are heated in a box with a flux, such as sand or clay, to the required pitch. These being hammered under a tilt, are welded into what is called single shear; the process performed over again gives double-shear steel. This article, properly prepared, and cast into ingots, becomes *cast steel.*

The most remarkable, as well as the most useful of the properties of steel, is the power which it has of changing permanently its degree of hardness and elasticity by being *tempered*—that is, by undergoing certain changes of temperature. No other metal is known to possess this property, and iron itself acquires it only when it is combined with a minute portion of carbon. If steel is heated to redness, and suddenly plunged in cold water, it is found to become extremely hard, but at the same time it is too brittle for use. On the other hand, if it be suffered to cool very gradually, it becomes more soft and ductile, but is deficient in strength. The process of tempering is intended to give to steel instruments a quality intermediate between brittleness and ductility, which shall insure them the proper degree of strength under the uses to which they are exposed. For this purpose, after the steel has been sufficiently hardened, it is partially softened, or let down to the proper temper, by heating it again in a less degree, or to a particular temperature suited to the degree of hardness required, after which it is again plunged in cold water. Different methods have been pursued for determining the temperature proper for giving the requisite temper to different instruments. One method, which answers sufficiently well in practice, is to observe the shades of colour which appear on the surface of the steel, and succeed each other as the temperature increases. Thus, at 430° of Fahrenheit, the colour is pale, and but slightly inclining to yellow: this is the temperature at which lancets are tempered; at 450°, a pale straw-colour appears, which is found suitable for the best razors and surgical instruments; at 470°, a full yellow is produced, suitable for penknives, common razors, &c.; at 490°, a brown colour appears, which is used to temper shears, scissors, garden-hoes, and chisels intended for cutting cold iron; at 510°, the brown becomes dappled with purple spots, which shew the proper heat for tempering axes, common chisels, plane-irons, &c.; at 530°, a purple colour is established, and at this degree the temper is given to table-knives and large shears; at 550°, a bright blue appears, used for swords and watch-springs; at 560°, the colour is a full blue, and is used for fine saws, augers, &c.; at 600°, a dark blue, approaching to black, has become settled, and is attended with the softest of all the grades of temper used only for the larger kinds of saws.

The inferior kinds of cutlery are made of blistered steel welded to iron. Tools of a better quality are manufactured from shear steel, while the sharpest and most delicate instruments are formed of cast steel. The first part of the process consists in forging, and is varied according to the kind of article to be formed. Common *table-knives* have the blade forged of steel, and welded to a piece of iron, out of which the shoulder, and part which enters the handle, are made, the shape being given to them by hammering in a die and *swage.* They are afterwards tempered and ground. *Forks* are made by forging the shank, and flattening the other end to the length intended for the prongs. The prongs are made by stamping the metal at a white heat between two dies, the uppermost of which is attached to a heavy weight, and falls from a height. The shape is thus given to the fork, leaving, however, a flat thin piece of metal between the prongs, which is afterwards cut out with a fly-press. They are subsequently filed, pointed, bent, hardened, and polished.

Blades of *penknives* are forged from the end of a rod of steel, and cut off, together with metal enough to form the joint. The small recess in which the nail is inserted to open the knife, is made with a curved chisel while the steel is hot. *Razors* are forged from cast steel, much in the same manner as knives. The anvil is commonly a little rounded at the sides, for the purpose of making the sides of the razor a little concave, and the edge thinner. In forging *scissors*, the shape is given to the different parts by hammering them upon different indented surfaces called *bosses.* The bows, which receive the finger and thumb, are made by punching a hole in the metal, and enlarging it by hammering it round a tool called a *beak* iron. The halves are finished by filing and grinding, and afterwards united by a joint.

Saws are made from steel-plates rolled for the purpose, and have their teeth cut or struck by a machine, finished by filing, and set by a suitable instrument. *Axes, adzes,* and other large tools, are forged from iron, and have a steel-piece welded on of the proper size, to form the edge.

To enable the steel to be wrought, it is brought to its softest state; but after the shape is given to the instrument, the steel is hardened and tempered by the methods already described. The remaining part of the manufacture consists in grinding, polishing, and setting the instrument, to produce a smooth surface and a sharp edge. The *grinding* is performed upon stones of various kinds, among which freestone is perhaps the most common. These stones are made to revolve by machinery, and move with prodigious velocity, so that the surface, in some cases, passes over 600 or 700 feet in a second, and stones have been burst by their own centrifugal force. For grinding flat surfaces, like those of saws, the largest stones are used; while for concave surfaces, like the sides of razors, smaller stones are used, on account of their greater convexity. The internal surfaces of scissors, forks, &c., which cannot be applied to the stone, are ground with sand and emery, applied with instruments of wood, leather, and other elastic substances. The last polish is given by a material composed chiefly of the oxide of iron. The edges are, lastly, *set* with hones and whetstones, according to the degree of keenness required. The test used by cutlers for determining the goodness of the edge and point of a lancet is, that it shall pass through a piece of soft leather without sensible resistance. *Needles* are polished by tying them in large bundles with emery and oil, and rolling them under a heavy plank till they become smooth by mutual attrition. The shape is previously given, and the eye made with a steel punch.

The uses of these three substances—cast iron, malleable iron, and steel—are so numerous and varied, that it would be impossible, even within the limits of our sheet, to give anything like a satisfactory detail. In one or other of its forms, iron is now employed for almost every purpose to which wood, or any of the other metals, can be applied in the arts of civilised life. In agriculture, architecture, ship-building, the fabrication of machinery, railways, the construction of implements and utensils, either for the objects of war or peace, and in the formation of all those articles which come under the designation of *hardwares*, its importance is pre-eminent—conferring upon Britain a wealth, power, and position which, but for the presence of her coal and iron, she could never have attained. But though iron is thus important, abundant, and common, it is by far the most difficult of the metals to bring into a state fit for use; and the discovery of the methods of working it seems to have been long posterior to the use of gold, silver, and copper. At what time it began to be made in this country, there is no means of ascertaining: ironworks are said to have been established by the Romans in the Forest of Dean in Gloucestershire; but be this as it may, it was not till a comparatively recent period that the manufacture began to assume anything like a national importance. 'Down to the seventeenth century'—we quote the *Cyclopædia of Commerce*—'the ore was entirely smelted with charcoal; and there was a considerable number of furnaces in those districts where wood and iron were plentiful, particularly the Weald of Kent, Surrey, and Sussex; but in course of time, wood-fuel becoming scarce, the trade was threatened with decay. Many attempts were made during the seventeenth and early part of the eighteenth century, to retard the decline by the use of pit-coal, but without effect; the simple hand-worked bellows, or the more powerful water-movement, which produced a sufficiency of blast for charcoal, having little effect upon coal; and the number of furnaces, which in 1619 was estimated by Lord Dudley—who in that year obtained a patent for smelting with coal—at 300, fell off towards the middle of the eighteenth century to 59. Science, however, came to the rescue of one of our greatest staple manufactures. In 1760, Smeaton erected a cylinder blasting-machine for the Carron Company, which, after some improvements, enabled the same furnace that formerly yielded 10 or 12 tons weekly, to produce 40. Shortly after this, Watt's improvement of the steam-engine, and its application to ironworks, not only revived the trade, but enabled it to distance all foreign competition. Ores that formerly could not be worked with profit, either from their inherent intractableness, or from the small proportion of metal they contained, were now advantageously submitted to the furnace, and more metal was extracted from the richest ores. Of recent inventions, by far the most important is the substitution of the *hot* for the *cold blast*, by artificially heating the currents of air impelled into the furnace. This discovery of Mr Neilson of the Clyde Ironworks, operates by obtaining a larger quantity of metal with a less degree of fuel. In 1829, with cold air, 1 ton of iron consumed 8 tons 1 hundredweight of coal; in 1833, with hot air, the same quantity of iron was procured with only 2 tons 5 hundredweights of coal.'

The result of these successive improvements and inventions presents the statistician with some of the most astonishing facts in the history of British manufactures. In 1740, the quantity of iron made in the United Kingdom did not exceed perhaps 25,000 tons; after the cylinder invention, it rose in 1796 to 124,879; in 1802, it was estimated at 170,000; in 1828, it rose to 702,584; in 1839, to 1,512,000; and at the present time, it exceeds 3,000,000 tons! It is true that the trade is subject to rapid and extensive fluctuations, the production rising and falling to the amount of several thousand tons, and the price ranging from £6 to £14, or even higher, a ton; but the immense demand now made by railways both at home and abroad—by ship-building, bridge-building, and the like—is not likely to suffer any considerable decline for several years to come. The other countries producing iron to any extent are—France, Belgium, Sweden, Saxony, Austria, Spain, and the United States; the whole furnishing an aggregate supply somewhat less than that of Great Britain, though in the last-mentioned country the trade has increased prodigiously since the application of the hot-blast to American anthracite has proved successful. At home, the chief seats of the iron trade are—Staffordshire, Shropshire, South Wales, Yorkshire, Derbyshire, and Lancashire in England; Lanarkshire and Stirlingshire in Scotland; in Ireland there are no ironworks of importance. The manufacture of hardwares, machines, engines, iron-steamers, locomotives, &c., is now more generally diffused throughout the country, though Birmingham and the towns around it still maintain their supremacy in general hardwares; Sheffield in cutlery; Manchester, Glasgow, and Dundee, in machinery; and Glasgow and Liverpool in ship-building.

Lead.

This is another of the metals which have been long and extensively used in the arts of civilised life. It has a grayish-blue colour, with a bright metallic lustre when newly cut, but soon tarnishes, and assumes a dull earthy aspect on exposure to the air. Its texture is close, like that of gold and silver; its specific gravity is about 11·45; and it is very malleable and ductile, but soft and unelastic. It is one of the least sonorous of the metals; melts at the low degree of 600° Fahrenheit; soils the fingers when rubbed; and emits a peculiar odour. Though readily oxidised by exposure to the air, the oxidisation does not proceed far; hence its durability for roofing and other external purposes. Pure or distilled water put into a clean leaden vessel, and exposed to the air, soon oxidises and corrodes it,

and delicate tests discover oxide of lead *in solution* in the water. River and spring waters do not act so readily on metallic lead, but few, if any, of the waters introduced into towns or houses for culinary purposes are *entirely* deficient in possessing a solvent action on lead. This action may only be $\frac{1}{100}$th to $\frac{1}{10}$th of a grain of lead in one gallon (70,000 grains) of water, when it may be reckoned harmless; or it may amount to a larger fraction, when it becomes dangerous to be taken into the animal system. Leaden cisterns may be used with impunity for the preservation of most ordinary spring or river waters, and the more so that the crust which forms upon the metal effectually retards all further action. As this crust partly consists of carbonate of lead, which is very poisonous, great care should be taken to prevent its diffusion through the water upon any occasion, as by scraping or cleaning the cistern. Natural waters, highly charged with carbonic acid, cannot, however, under any circumstances be kept in lead vessels, or passed through leaden pipes with safety.

Fourteen or fifteen ores of lead are known to mineralogists; but that of *galena*, a sulphuret of the metal, is the only one occurring in sufficient quantities to become an object of mining and metallurgy. It is found but sparingly in the primitive crystalline rocks, more plentifully in the transition schists and slates, and most abundantly in the transition and mountain limestones. The principal lead-mining countries are Britain; Saxony, Bohemia, and other states of Germany; Spain; France; and Missouri in the United States. The lead-mines of Britain are of great importance; and those of Derbyshire are said to have been worked prior to the Roman invasion. The most productive at present are situated in Northumberland, Cumberland, Durham, Derbyshire, Flintshire, Isle of Man, and at Leadhills in Scotland. Nearly the whole produce is derived from galena, in the proportion of about 85 per cent. of pure metal.

When lead ore comes from the mine, the first operation is to wash and sort it into heaps of different qualities; this is done either by putting the ore into a trough, and stirring it, or filling a sieve, the meshes of which are made of iron, and immersing it in a vat full of water. Another process is to put the ore upon a *grid* or screen, which consists of a number of bars of iron placed parallel to each other, about an inch apart. Over this grating, a stream of water flows, which washes away all impurities, and also separates the small pieces of ore from the large. The smaller pieces are then collected into a finer sieve, and washed again, and all pure ore which may still be amongst them is carefully picked out with an iron scraper or *crimp*. This washing is greatly facilitated by the specific gravity of the metal. The ore containing most galena sinks first, and is found next the bottom of the vat; a second quality of ore will be found on the top of this, and the inferior kinds above it. When the sieve is immersed in the water, it is shaken pretty severely, which causes the ore in a manner to float, and allows the heavier pieces to sink to the bottom. The mixed ore—that is, such as contains stone and other impurities in the lump, along with pure galena—is then sent to the grinding-mill. This consists either of a series of stampers, which pound the ore, or of a pair of fluted cylinders, through which the ore is made to pass: it is afterwards ground to the requisite fineness by smooth rollers. The mixed ore, after being ground, is again washed, and the pure galena separated from the impurities.

There are two kinds of furnaces used in the smelting of lead ore—a reverberatory furnace (see fig. 8), called a *cupola*, and the other known by the name of the *Scotch furnace*. The former, in the interior, is generally 8 feet long, 6 wide, and 2 high at the centre. The fire is placed at one extremity, and is separated from the smelting part by a wall, A, which is built about half the height of the furnace. The hearth upon which the ore is placed is composed of furnace-slags, and it slopes from the wall which separates it from the fire to the other end, B, of the furnace, and is hollowed from the sides to the centre. This is enclosed by an arched roof, in the middle of which is a small aperture for admitting the ore from a hopper, H, placed above it. The Scotch furnace is much of the same nature as the above, except that the hearth, sides, and sole-plate are made of cast iron, from two to three inches thick. The roasting is performed with peat and coke, and the furnace is urged by bellows. About 20 hundredweights of ore are usually put into the furnace at a time, which is spread equally over the hearth with a rake. For the first two hours, no regular fire is made, a gentle heat merely being kept up by putting small coal on the furnace, the doors of which are kept shut. This is called the roasting process, which is performed principally for the purpose of dispelling all sulphureous vapours from the ore. At the end of two hours, the fire is raised, and the metallic lead soon begins to flow from the ore. The smelter and his assistant now stir the ore at intervals, and a shovelful of quicklime is thrown in. This is done in order to liberate the oxide of lead from the ore, and allow it to react upon any sulphuret which may have resisted the roasting. The heat is again increased, and the stirring continued. In about four hours from the commencement, the furnace receives its greatest heat, after which a tap-hole is opened, and the lead runs into an outer basin. From this it is cast in semi-cylindrical moulds, and receives the name of *pigs* or bars.

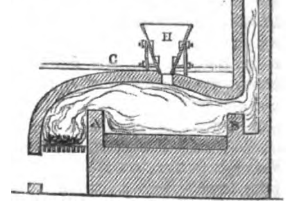


Fig. 8.

Metallic lead is employed for numerous purposes in the arts: rolled into *sheets*, it is used for roofing, lining of cisterns, tea-boxes, &c.; cast into *pipes*, it is employed for conducting of water, gas, and the like; and alloyed with arsenic, and dropped through perforated trays from lofty towers, it forms *shot* of various sizes. Alloyed with tin in different proportions, it constitutes *solder* and *pewter;* and with antimony and tin, it forms *type* and *stereotype metal*. Combined with oxygen, it constitutes *massicot*, a protoxide of a pale yellow colour; *litharge*, also a semi-crystalline protoxide, obtained in separating silver from lead ores, enters largely into the composition of flint-glass; *red-lead*, a deutoxide, is extensively employed as a pigment, and also in the manufacture of flint-glass; *white-lead*, a carbonate of the metal (see CHEMISTRY) is a well-known paint; as is also the beautiful yellow chromate; while the acetate of lead, commonly known as *sugar-of-lead*, is employed for various purposes in the arts and in medicine.

In the reduction and application of lead to the above purposes, a considerable amount of mechanical and chemical ingenuity is required. Thus, in the preparation of sheet-lead, a plate is first cast, and then subjected to successive *millings* between heavy rollers, which extend and reduce it to the desired thickness. The thickness is regulated by screw-work, which keeps the rollers apart, so as to produce a sheet varying from half an inch to the thinness of the finest writing-paper. Still greater ingenuity is exhibited in pipe-drawing. A *plug*, or thick short pipe, is first cast in a mould; a mandrel, or steel rod, of the desired bore is inserted in this pipe, which is then drawn by machinery through a succession of gradually decreasing holes in a steel-plate or die. In producing a two-inch pipe, no fewer than sixteen dies are employed, the diameters of which

descend in a regular series. The hole through the die is conical—that is, larger on one side of the die than on the other; and the lead enters the hole at the widest part, whereby a process of compression is undergone; but at a certain point in the operations, a *cutting-die* is introduced—that is, one wherein the lead is at once exposed to a cutting-edge, the result of which is, that a thin film is cut or scraped from the whole surface of the pipe. The elongated pipe is now removed from the mandrel, coiled up, and sent to the plumber. By this process, lead-pipes of good quality are obtained, but in lengths of only 20 to 30 feet; and where longer lengths are required without a join, recourse is had to the hydraulic pipe-press. This machine contains lead in a molten state; and by means of a piston-rod worked by a hydraulic press, the molten lead is forced through a mould the exact size of the pipe required. As the pipe escapes from the press, it is coiled round a drum, and can be obtained of almost any length.

Shot is formed by dropping an alloy of lead and arsenic through perforated trays or colanders, from the top of lofty towers, into a cistern of water beneath; the same result is more economically obtained by dropping the metal from the surface to the bottom of some waste coal-shaft, as is done at Newcastle. The perforations of the colanders are of sizes ranging from $\frac{1}{6}$th to $\frac{1}{30}$th of an inch in diameter; and on passing through these, the melted metal assumes a globular form, cools partially in falling, and ultimately settles in the cistern in drops less or more spherical. These are next assorted by being passed through sieves, which retain all imperfect forms; and still further, by being passed over an inclined plane of polished iron, when the well-shaped shot descend with an impetus sufficient to carry them into a trough at some distance from the end of the incline, while the imperfect forms travel slowly, and drop 'dead,' as the workmen express it, almost over the verge of the plane. The dark glossy hue of shot is obtained by churning it with powdered black-lead in revolving cast-iron barrels, a process which also assists in producing a still more spherical form. Leaden bullets are cast in moulds; but all the former modes of casting, cutting, and rolling shot are now abandoned. None of the chemical preparations of lead involve any peculiar difficulty either in their manufacture or application; the only contingent evil is their poisonous character, which manifests itself more or less on the constitutions of painters, plumbers, whitelead-makers, and the like. Lead, indeed, is a metal requiring very cautious use in any form, and ought to be avoided in the manufacture of all culinary, dairy, brewing, and other utensils employed in the preparation of human food.

The amount of lead annually smelted in Britain is estimated at 48,000 tons or thereby; which, at the present price, would make the value of the produce little short of £1,000,000 sterling. About 15,000 tons are annually exported, partly in pigs, and partly in sheet, shot, red-lead, and litharge.

Zinc.

Though known as early as the beginning of the sixteenth century, the numerous and important applications of zinc, or *spelter* as it used to be called, are for the most part of very recent date. Its distinguishing characteristics are bluish-white colour and lustre; specific gravity, 6·89; at common temperatures, tough and intractable; but heated to between 220° and 320° Fahrenheit, it becomes malleable and ductile, so that it may be hammered out, rolled into sheets, perforated, and even drawn into wire of such tenacity, that $\frac{1}{18}$th of an inch in diameter is capable of sustaining a weight of twenty-six pounds. Heated beyond that point—say between 400° and 500° Fahrenheit—it again becomes so brittle, that it may be reduced to powder in a mortar. It melts at 773°; and heated beyond this, it takes fire in the open air, and burns with a brilliant bluish flame. The metal is obtained from two ores—namely, *calamine*, a native carbonate; and *blende*, or *black jack*, a native sulphuret. These ores occur in two geological positions—namely, either in the carboniferous or in the magnesian limestone, associated with galena, and sometimes with the ores of cadmium.

Zinc ores are found in Britain, especially in Flintshire, Derbyshire, and Cumberland; but the quality of the British metal is inferior to that of Germany, from whence, *vià* Hamburg, about 170,000 hundredweights are annually imported, commonly as ballast for ships bringing wool. Of this amount, about one-half is kept for home consumption, and the remainder for exportation, chiefly to India, which, previous to 1820, obtained her supply from China. The ores are roasted and mixed with charcoal; the mixture is put into a kind of crucible, closed at top, and perforated at bottom by an iron tube, which passes through the grate of the furnace into water; and the vapour of the zinc distils downwards through the tube, and is condensed in the water. The first portions are impure, containing arsenic, and often cadmium, in which case the vapour burns with what the workmen call a *brown blaze;* when the *blue blaze* appears, the zinc is collected. The above is the English method of reduction; in Germany and the Netherlands, the principle is much the same, but somewhat differently applied.

Zinc being a cheap and light metal, and one which, when superficially oxidised, long resists the further action of air and water, it is now employed as a substitute for lead in lining cisterns and baths, covering roofs, forming water-spouts, and the like. It has also been used of late in the manufacture of kitchen and dairy utensils. It is likewise wrought into buttons and other small-wares; and zinc-plates have been a considerable while in use in the transfer of printing, under the title of *zincography*. Its sulphate and oxide are employed in medicine; and with copper it forms, as already described, the well-known alloy, brass. Though the action of water upon zinc be scarcely appreciable, after it has once been coated with the oxide, yet the addition of a little acid—as sulphuric—dissolves and removes this coating, and further oxidation proceeds with rapidity. It is this action which renders zinc so powerful a generator of electricity in the voltaic pile or battery. (See Voltaic Electricity.)

Aluminum.

This metal has recently been introduced before the public as one which is likely to be employed in our arts and manufactures on a large scale. It was reserved for M. Deville of the chemical works of Javel to suggest a mode of preparation by which this metal could be economically prepared. The process he follows is to act on chloride of aluminum by means of sodium. The chloride of aluminum is artificially prepared by passing chlorine gas through a layer of alumina and coal-tar previously calcined, and contained in a gas-retort. The chloride of aluminum volatilises, and condenses in a receiving chamber lined with glazed fire-brick, as a compact substance of considerable density and sulphur-yellow colour. It may be purified from iron by volatilising it a second time, and allowing the vapour to pass through a tube heated to 750° Fahrenheit, and studded with points of metallic iron. The latter arrest and fix the vapours of perchloride of iron, and allow to pass only the pure chloride of aluminum, which passing into a condensing arrangement, is deposited in colourless and transparent crystals. The pure chloride of aluminum is mixed with sodium introduced into metallic tubes and heated, when the sodium seizes the chlorine to form chloride of sodium—common salt—and sets free the aluminum. The experiments of Deville were conducted on a large scale, at the cost of the Emperor of France; and the trials shewed that the production of aluminum in quantity was quite practicable, and was not very costly. This inquiry has likewise been of great service, as it has

placed at the disposal of scientific men the metal sodium at a mere fraction of the price previously paid for it.

Aluminum is a white metal, somewhat resembling tin in external appearance, but with a much less specific gravity. It is not tarnished when exposed to air; even when raised to a high temperature, it is not oxidised; so that it may be regarded as unalterable. It possesses remarkable sonorous properties, and in this respect is not outrivalled by the most sonorous alloys, such as bell-metal. No other single or pure metal possesses the sonorous character in an unmixed or unalloyed condition. Aluminum appears likely soon to rank as one of the most useful and serviceable of the metals. It has already been manufactured into medals, trinkets, and watch-wheels of exquisite workmanship; and from its great lightness and unalterable character, it is now—1857—being made into eagles to surmount the standards in the French army, in preference to the other metals which are much more dense, and are more liable to be tarnished. The non-tarnishing property of aluminum is even carried into its alloys. A compound of seventy-five parts of iron, and twenty-five parts of aluminum, will not oxidise or rust in damp air, though the iron by itself rapidly does so.

Tin.

Tin was known to the ancient nations of the Levant, who obtained it chiefly from Spain and Britain. It is a white, brilliant metal; has a slight taste and smell when rubbed; is malleable to a considerable degree, but is inferior in ductility and tenacity. Its hardness is intermediate between that of gold and lead; its specific gravity is about 7·3; it melts at 442° Fahrenheit, and at a white heat takes fire and burns with a bright flame. It oxidises but slowly on exposure to air and moisture; hence its value in coating or tinning more oxidisable metals, as iron. Tin is rather a rare metal; and is principally found in primitive rocks, where it occurs chiefly in veins, but partly also disseminated, and in beds. There are only two ores of the metal known—the double sulphuret, which is rare; and the native peroxide, from which the commercial supplies of the metal are obtained.

This latter ore is found abundantly in Cornwall and the western district of Devonshire; in Germany, Bohemia, and Hungary; in Chile and Mexico; and in Malacca and Banca in the East Indies. The tinstone of Britain is chiefly obtained from mines; but considerable quantities are sometimes discovered in alluvial soils—the débris of rocks in which the ore was originally imbedded. Repeated washings, by means of running water, being the chief process by which the ore is separated from such débris, the name of *stream-work* is commonly applied to this method of obtaining it. On one occasion, the water being excluded from a branch of Falmouth harbour, a bed of rounded masses of tin-ore, from two to ten feet thick, was found fifty feet below a bed of alluvium—£50,000 is said to have been made by this discovery.

The ore, in whatever way obtained, is first broken into small fragments, then pounded in stamping-mills, washed, sifted, and roasted. It is next reduced by smelting with coal and a flux of lime, under a very strong heat, which is kept up for eight or nine hours. The liquid tin, on being run off from the slag, is still mixed up with iron, arsenic, and other impurities, and has to undergo fresh smeltings, after which it is cast into granite moulds, capable of containing about three hundredweights each. In this form it is known as *block* or *bar tin*—a term generally used in contradistinction to *grain-tin*, which is obtained from stream-ore, somewhat differently treated. After the stream-tin ore has been dressed and pounded, it is smelted with wood-charcoal, run off into iron vessels, and there kept liquid by a gentle heat, till, by repeated agitation with pieces of charcoal, all impurities are expelled. It is finally removed by ladles, and poured into small moulds. The grain or stream tin so obtained is of superior quality, and is employed by dyers, and for the finer purposes.

The uses of tin are both numerous and important. Besides being employed in the formation of a variety of utensils, it is largely used in *tinning* copper and iron-plate, to protect them from rust—an art which originated in Saxony, and was made known in Britain about two centuries ago. It consists in carefully cleaning the surface of the plate with sal-ammoniac, or with hydrochloric (muriatic) acid, rubbing it well, and then immersing it in melted tin, by which it acquires a thin and equable coating. Vessels are coated internally by heating them, pouring in a certain quantity of melted tin, and then rotating them, so that the tin may come in contact with every part of the surface. Alloyed with antimony, copper, bismuth, and lead, tin forms *pewter;* it enters into the composition of *bell-metal*, *type-metal*, and *solder;* it is used in the process of enamelling; in silvering, or rather tinning, looking-glasses, in coating pins; by dyers and calico-printers as a *mordant* when dissolved in hydrochloric acid; largely in the form of *foil* or leaf, which is made by beating; its oxide is much used in polishing, under the name of *putty-powder;* and the *purple of Cassius*, so called from its inventor, is a union of protochloride of tin with perchloride of gold.

The annual produce of the British tin-mines is estimated at 4000 tons, worth from £65 to £80 a ton. About 1500 tons of unwrought tin are annually exported, principally to France, Italy, and Russia; and this, exclusive of tin, pewter-wares, and tin-plate, to the value of £400,000 yearly, sent to the United States, Italy, Germany, France, the colonies, &c. The amount of crude tin brought from the East is very variable, ranging generally between 500 and 1500 tons per annum.

Mercury or Quicksilver.

This is a well-known metal, of a brilliant silver-white colour, fluid and mobile at ordinary temperatures; hence the name *live*, or *quick*, silver. In this property of fluidity, it differs from all other metals—never being solid, unless when subjected to a degree of cold equal to —39° or —40° Fahrenheit. In this condition it has been obtained by arctic explorers, who, under extreme depressions of temperature, found their barometers and thermometers useless, and who, for curiosity's sake, have shot bullets of it from their muskets. When solid, it is found to be malleable, a fact of no practical importance, however, as it instantly passes into the fluid state on being brought to a higher temperature than − 40°: it boils and vaporises at about 600° Fahrenheit. Its specific gravity is about 13·59; thus ranking above all other metals, with the exception of platinum, gold, and tungsten. It is found native in small quantities—that is, in minute dewy globules; but for commercial purposes it is always extracted from the ore called *cinnabar*. This ore is a sulphuret of the metal, of a red colour—except in the hepatic variety, which is gray—massive and crystallised, occurring in veins, and distributed variously through the matrix of the veinstone. It is found but sparingly in the primitive rocks; the principal deposits of the mercurial ores being, in all parts of the world, in the middle secondary strata—that is, in the upper portions of the coal-measures, and in the magnesian limestone and new red sandstone. In these formations the ore occurs either in irregular veins, or is combined with the sandstones, bituminous schists, and indurated clays.

The most productive mines of cinnabar are those of Almaden, near Cordova, in Spain; of Idria in Austria; of Huancavelica in Peru, at an elevation of 14,500 feet above the sea; and of New Almaden in California. Quicksilver is also produced in several of the Chinese provinces, and sparingly in one or two localities in Rhenish Bavaria, Bohemia, and Hungary. The mines of Idria, which were discovered in 1497, yield annually about 150 tons of the pure metal; but could readily

supply four times that amount, were it not for certain absurd restrictions imposed upon the produce by the Austrian government. The veins at Almaden, which range from twelve to twenty feet in thickness, have been worked for nearly 3000 years; at all events, Pliny records that the Greeks imported red cinnabar from Spain 700 years before the Christian era, and that Rome in his time annually received 700,000 pounds from the same province. The usual method of reducing the ores is by distillation. The minerals brought out of the mine are broken up, picked by women and children, pulverised, and sometimes washed. In some places, the richer ores are separately burnt; but it is more usual, and considered more economical, to mix the richer with the poorer ores, and expose the whole mass together to the action of heat in closed retorts, which also contain a certain proportion of limestone. The retorts, filled with the mixture of mercury, ore, and lime, are ranged, to the number of twenty or more, in a furnace, where heat is applied. Each retort communicates with a vessel of water, in which the vapours of the mercury are condensed. In the mines of Idria, a ruder method is adopted: the ores are roasted in a kind of oven, and the vapours ascend into condensers, where the little drops of mercury collect, and are conducted into a porphyry vessel placed to receive them.

The imports of mercury into this country, chiefly from the mines of Almaden, are about 2,200,000 pounds annually, of which little more than an eighth are retained for home consumption. The remainder is re-exported, principally to South America, Mexico, the United States, and the East Indies; while smaller shipments are made to Russia, Belgium, and other countries. During the war, when the intercourse between Europe and America was interrupted, the price of quicksilver rose to such a height in the latter country that it answered to import it from China. From the peculiar character of the metal, it is transported either in iron bottles, in small leathern bags, or, as from China, in short joints of the bamboo. Mercury is often adulterated by an admixture of lead, bismuth, zinc, and tin; in which state it is less lustrous, becomes covered with a whitish film, and is not so mobile, or readily divisible into minute globules.

Mercury is principally employed for *amalgamation* with other metals, chiefly gold and silver, so as to extract them from their ores; and it is almost solely for this purpose that it is imported into South America and Mexico. It is used also in gilding, in silvering mirrors, in filling thermometer and barometer tubes, in various philosophical apparatus; and in chemistry it furnishes the only means of collecting, in the pneumatic trough, such gases as would be absorbed by water. In medicine, it is employed in several forms: the whitish insipid powder termed *calomel* is the subchloride of mercury; and the acrid, nauseous, white substance known as *corrosive sublimate* is the perchloride. This sublimate has been applied as an antiseptic in the prevention of the dry-rot in timber, of the mildewing of sailcloth, and the like. Mercury is also used in the making of *vermilion*, that beautiful pigment being prepared from an artificial cinnabar, composed of eight parts of mercury and one of sulphur. When sulphur and mercury are triturated together in a mortar, the former gradually disappears, and the whole assumes the form of a black powder, denominated *ethiops mineral;* if this powder be heated red-hot, it sublimes, and on a proper vessel being placed to receive it, a cake is obtained, of a fine red colour, which, when reduced to powder, forms the vermilion of commerce. An amalgam of mercury and silver is used by dentists for stopping hollow and decayed teeth.

Antimony.

This metal was discovered by Basil Valentine in 1490, and has since been extensively employed in medicine, in the composition of printing-types, stereotype-plates, music-plates, and the like; and also in the manufacture of the white-metal utensils now so generally used as substitutes for silver. When pure, it is of a silver-white colour, is brittle, has a specific gravity of 6·8, and melts readily at a red heat. When heated in open crucibles, it gradually combines with the oxygen of the atmosphere, and flies off in the form of a white vapour. The oxides and salts of antimony are used in medicine, their general effects being purgative, sudorific, and emetic. The metallic ore of commerce contains sulphur and other impurities, and is much more easily fused than the pure metal, which has a hardness about that of gold. Its tenacity is also considerable—a wire of $\frac{1}{10}$th of an inch in diameter being capable of supporting a weight of ten pounds.

Antimony ore is found at Rosenau in Hungary, in Saxony and the Harz, in Spain, France, Siberia, Mexico, the Indian Archipelago, and in Cornwall and Ayrshire in Great Britain. It is usually of a lead-gray colour, is crystallised, possesses considerable splendour, and is very apt, by the uninitiated, to be mistaken for an ore of lead. *Crude* antimony is the name given in commerce to the sulphuret of the metal, after being separated from the impurities of the ore by fusion with charcoal; and *regulus* of antimony is the pure metal, after being separated from the sulphur, by being mixed with tartar and exposed to heat. The powder of the sulphuret is very black, and was employed by women in ancient times to stain their eyebrows and eyelids.

Antimony is never applied to any useful purpose as an independent metal, in consequence of its brittleness and liability to corrosion; but it forms several valuable and extensively employed alloys. Thus, alloyed with lead, in the proportion of 2 to 6, with greater or less proportions of copper or tin, it constitutes the metal used for printing-types; mixed with lead alone, the compound forms the rather brittle plates upon which music is engraved; and an alloy of 112 lead, 18 antimony, and 2 block tin, forms a convenient stereotype metal. These alloys have the property of expanding as they cool; the consequence of which is, that the types come out of the moulds with sharp and well-defined edges. Hard pewter is made of 12 parts of tin and 1 of antimony; and the Britannia or white metal spoons and tea-pots, now so much in use, are composed of 100 tin, 8 antimony, 2 bismuth, and 2 copper. Antimony also unites with iron, forming a hard whitish alloy; and the smallest portion fused with gold renders that otherwise soft and ductile metal brittle and unmalleable. The manufacturer of pastes or factitious gems employs the oxide of antimony to give colour to his so-called beryls, Oriental topazes, and yellow diamonds. Six parts dry nitrate of potash, two sulphur, and one sulphuret of antimony, reduced to a fine powder, form the blue or Bengal light used as a signal at sea.

Bismuth.

This metal is of a brittle crystalline texture, reddish-white in colour, and fusible at the temperature of 497°. Its hardness is between that of copper and lead; it is scarcely malleable, breaks under the hammer, and cannot be drawn into wire. Bismuth is by no means a common metal, and is usually obtained in a combined state in Cornwall, France, Bohemia, Saxony, and Sweden. As met with in commerce, it is generally mingled with impurities of iron, arsenic, or other metals.

It is used as a *flux*—that is, for communicating fusibility to other metals; *solder*, for example, consisting of 1 bismuth, 5 lead, and 3 tin—an alloy which melts at a lower temperature than lead. It is also employed in the formation of some kinds of pewter, printers' types, and various metallic mixtures. Eight parts of bismuth, 5 of lead, and 3 of tin, constitute the fusible metal sometimes called Newton's, from its discoverer, which melts at little more than 200°, or under the heat

of boiling water, and may be fused over a candle in a piece of stiff paper, without burning the paper. A small addition of mercury aids the fusibility; and such alloys are sometimes used in taking casts of anatomical preparations. Bismuth forms the basis of sympathetic ink; and the powder called *pearl-white*, used in medicine, is obtained from the nitrate of the metal, which, when dropped into water, falls down as a white powder insoluble in water. The nitrate has also been employed as a mordant for lilac and violet dyes in calico-printing. Some of its forms seem likewise to be employed in the preparation of cosmetics, for a story is told of a lady, who, on visiting one of the watering-places in Germany, emerged from the bath as a 'lady of colour,' the chemical action of the mineral water having turned almost to blackness a cosmetic containing bismuth which had been previously applied to the face.

Cobalt.

Cobalt is a reddish-gray brittle metal, somewhat soft, fusible at a temperature a little below that required for the fusion of iron. The finest ores are found in Saxony, where it received its name (*kobold*, a devil); a term applied to it by the miners, who considered it unfavourable to the presence of the more important metals. It is never employed in the arts in the metallic or separate state; but the impure oxides of the metal, called *zaffre* and *smalts*, are extensively used as colouring materials.

The oxide of cobalt is an invaluable article in the manufacture of porcelain and pottery; all the blue colours of which are derived from that substance. When fused with glass, it communicates a blue tint to that material, without impairing its transparency; and what is especially valuable, this colour is not impaired by very high temperatures. So great is the colouring power of oxide of cobalt on vitrifiable substances, that 1 grain gives a full blue to 240 of glass! Cobalt blue, or Thenard's blue, is a beautiful pigment, prepared from the phosphate of cobalt, and which may be employed by decorative painters and artists as a substitute for ultramarine. Smalts, of which we annually import about 146,000 pounds, are prepared principally in Norway and Germany, by melting oxide of cobalt with silicious earth and potash. Zaffre, of which we import more than double that amount, is manufactured chiefly in Saxony and Prussia.

Nickel.

This metal is of a brilliant white colour, resembling silver; ductile and malleable, and capable of receiving a high polish. It is difficult of fusion, but melts at a lower temperature than iron: it undergoes little or no change by exposure to air and moisture. It is found in all meteoric iron; but its principal ore is a copper-coloured mineral found in Westphalia, and called *kupfer-nickel;* nickel being a term of detraction used by the German miners, who expected from the colour of the ore to find that it contained copper. The cobalt ores are the most fruitful sources of this kupfer-nickel, or *speiss*, which is reduced to the metallic state by roasting, dissolving, evaporating, and other processes. Alloyed with copper, nickel forms argentane, or German silver; and since this compound became an object of commercial importance, the extraction of the metal has been undertaken upon a considerable scale. It is also employed in potteries and in the manufacture of porcelain. It is, to a certain degree, susceptible of magnetism, and mariners' compasses might be made of it. The alloys of nickel, from their whiteness, hardness, and infusibility, form excellent bases for the manufacture of electro-plate.

Arsenic.

This metal, discovered by Brandt in 1733, is exceedingly brittle, of a strong metallic lustre and white colour, running into steel-gray. Its specific gravity is 5·67; when heated, it volatilises, emitting a strong odour of garlic before it fuses, and is readily inflammable. The pure metal is so brittle that it may be easily reduced to a very fine powder by trituration in a mortar. The *arsenic of commerce* is the white oxide of the metal, or, more accurately, *arsenious acid*—a compound which is obtained chiefly from Bohemia and Saxony, in roasting the cobalt ores for making zaffre, and also by sublimation from arsenical iron pyrites. Arsenious acid is originally prepared in cakes, brittle, white, faintly sweetish in taste, and more or less translucent; for medicinal purposes, these cakes undergo sublimation, in order to get rid of sulphur and other impurities. In the shops, it is usually sold in the form of a white gritty powder.

Arsenious acid, though one of the most virulent poisons, is used in medicine, forming a notable ingredient, for example, in what are called ague-drops. It is also present as an ingredient in *Scheele's green* and other dyes, in the manufacture of flint-glass, and is employed in rare instances by candlemakers, to impart to their candles a white and waxy appearance. With sulphur, arsenic forms two compounds, known in commerce by the names of *realgar* and *orpiment;* the former a red sulphuret found in Bohemia and Saxony, and used as a pigment, as well as in pyrotechnical compositions; and the latter a yellow sulphuret, found native in China, South America, &c., and produced artificially in Saxony, and employed in dyeing and calico-printing. The finer native varieties are reserved for artists.

'It is often said,' observes Mr Brande, 'that the bodies of persons poisoned by arsenic are very prone to putrefaction; but this is not always the case. After death, the stomach and bowels are usually found inflamed, but often slightly so; and it appears, from Sir Benjamin Brodie's observations, that this poison kills by some peculiar action upon the heart and nervous system. The treatment of persons thus poisoned, consists in promoting vomiting by an emetic, composed of a solution of twenty grains of sulphate of zinc in two ounces of water, aided by copious draughts of warm barley-water or gruel; but the most effective means of getting rid of the arsenic is by the use of the stomach-pump, which, when immediately resorted to, has often saved the patient. The only ready means of ascertaining the presence of white arsenic is by heating the suspected substance upon a red-hot coal, or in the flame of a candle, when it will emit the peculiar arsenical odour resembling that of garlic; but the treatment of persons poisoned by arsenic, and its detection in doubtful cases, must be left to the medical man and the chemist. It is impossible too strongly to represent the evil which results from the unfettered sale of arsenic, and from the unwarrantable use of it as a poison for rats and as a veterinary remedy; for it is thus that it finds its way into culinary vessels, gets accidentally mixed with articles of food, and that bottles which have contained it are used for beer, wine, and other beverages. Its sale should be rigidly prohibited by all save regularly qualified druggists.'

Platinum.

Platinum, or platina, was unknown in Europe till about the middle of the last century, when it began to be imported in small quantities from South America. It is of a whitish silvery colour; hence its name, from the Spanish word *plata*, silver. It is the heaviest, the most difficult of fusion, the most ductile, and the most flexible of the known metals, having a specific gravity of 21·5, and capable of being hammered into leaves, or drawn into wires, of extreme tenuity. Its hardness is intermediate between that of copper and iron; and though very infusible, it is malleable, and capable of being welded at a white heat, either one piece to another, or to a bit of iron or steel. It is not in the

least affected by the action of air or water, and is not attacked by any of the pure acids; but is dissolved by chlorine and nitro-hydrochloric acid (*aqua regia*). In ductility and indestructibility, it is hardly inferior to gold. When a perfectly clean surface of platinum is presented to a mixture of oxygen and hydrogen gas, it has the extraordinary quality of causing them to combine, so as to form water, and often with such rapidity as to render the metal red hot.

Platinum attracted little notice until the mode of purifying it and rendering it malleable was discovered by Dr Wollaston. It is found in the metallic state in Brazil and Peru; at Antioquia in South America; in Estremadura in Spain; and latterly, in considerable quantities, in the Uralian Mountains. Its appearance, in the rough state in which it is imported, is that of small grains or scales, of a metallic lustre, darker than silver, and extremely heavy. In this state it is combined with palladium, rhodium, titanium, iron, gold, or other metals. The particles are seldom larger than a pea, but pieces have been found as large as a hazel-nut; and in 1831, a mass of native metal was discovered in Demidoff's gold-mines in Russia, weighing upwards of twenty pounds!

The perfection with which vessels of platinum resist the action of heat and air, of most of the acids, and of sulphur and mercury, renders them peculiarly valuable in many chemical applications; so that notwithstanding the high value of the metal, which is between four and five times its weight of silver, it is now much employed for crucibles (fig. 9), retorts for the distillation of sulphuric acid, mirrors for reflecting telescopes, by gunsmiths, and others. Its property of being welded, either one piece with another, or with iron and steel, admits of many useful applications in the arts. From its scarcity and indestructibility, it has been proposed to use it for coinage; and such coins of the respective values of 3, 6, and 20 silver rubles are now current in the Russian Empire.

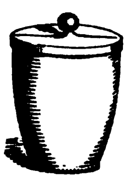


Fig. 9.

Manganese.

This is a very brittle metal, of a dusky white colour, and without either malleability or ductility. The substance known in commerce under that name, however, is the peroxide, or the black oxide of the metal. It occurs native in the Harz Mountains, in Piedmont, in the Mendip Hills in Somerset, and the counties of Devon and Aberdeen. It is found in a variety of forms: most commonly it is of an earthy appearance, and mixed with other ingredients; but sometimes in crystals of a black colour and metallic lustre. This mineral was described by Scheele, in 1774, as a peculiar earth; but in the same year, Gahn shewed that it was the oxide of a true metallic substance. The metal separately is of no known use, but the binoxide is a source of oxygen, and is largely employed in the decomposition of common salt for the production of chlorine for bleaching. It is also used by potters and glass-makers as a glaze or pigment; and lately, it has been used in calico-printing as the source of certain brown colours. Still more recent investigations have shewn that a certain proportion of manganese added to steel manufactured from British iron, produces a cast steel nearly equal to that obtained from Swedish iron. The ore of manganese, known in England by the name of *black wadd*, is remarkable for its spontaneous inflammation with oil. The pure metal can only be kept in closely stoppered bottles, under naphtha, like potassium; because, when in contact with air, it is rapidly oxidised, and falls into a dark-brown powder.

Chromium.

Chromium—from the Greek word *chroma*, colour—discovered by Vauquelin in 1797, is a metal resembling iron in colour, brittle, and difficult of fusion. It is rarely to be found in its metallic state; but several of its compounds, as chromate of iron and chromate of lead, are well known in commerce. The former, a compound of oxide of chrome with oxide of iron, is found in Unst in Shetland, in France, and near Baltimore in America. It appears massive, or in crystals of a dark colour and imperfect metallic lustre. It is employed in the manufacture of chromate of potash, a yellow salt, largely manufactured for the use of calico-printers. Chromate of lead is found native in the gold-mines of Berezov in Siberia, in the Ural Mountains, and in Brazil, and is easily prepared, by mixing chromate of potash with a soluble salt of lead. It occurs massive and crystallised, of a deep orange-red colour; but when reduced to powder, it becomes orange-yellow. It forms an excellent pigment, and is used both in oil and water-colours, in calico-printing, and in dyeing. The other compounds chiefly in use are the *oxide of chromium*, employed to give a green colour to glass and to porcelain; and *chromic acid*, which, from its property of destroying most vegetable and animal colouring matters, is advantageously employed in calico-printing. It is this acid which gives colour to the ruby; and the green of the emerald is owing to the oxide of chromium.

Cadmium.

This metal was discovered by Professor Stronmeyer of Göttingen about the beginning of 1818. It occurs chiefly in Silesia, combined to the extent of between 2 and 11 per cent. with several ores of zinc, and is reduced to the metallic state by a somewhat complicated process of solutions and precipitations. The pure metal has the colour and lustre of tin, and is susceptible of a fine polish. It is soft, easily bent, filed, and cut, and soils like lead any surface rubbed with it. It is harder and more tenacious than tin, and emits a creaking sound, when heated, like that metal. It is very ductile, and may be drawn out into fine wire, and hammered into thin leaves without cracking at the edges. Its specific gravity is somewhat less than 9; it is very fusible, melting at a point much below redness. Its scarcity prevents its employment in the arts; but it has been sparingly used in dentistry. The sulphate of cadmium has been applied to the eyes for removing specks from the cornea.

Palladium.

This rare substance was discovered in 1803 by Dr Wollaston, when experimenting on the ores of platinum, which it greatly resembles in colour and lustre. A native alloy of gold with palladium is found in Brazil, and imported into England. The pure metal is ductile and malleable, has a specific gravity of 11·5, and its fusibility is intermediate between that of gold and iron. It is oxidised and dissolved by nitric acid; its properties, however, are yet imperfectly known, nor is it, so far as we know, applied to any economical purpose, unless sometimes for the graduated scales of astronomical instruments. The Wollaston medal of the Geological Society of London is very appropriately made of palladium.

Rare Metals.

The remaining metals—osmium, iridium, tungsten, molybdenum, rhodium, vanadium, &c.—have not as yet been applied to any economical purpose. Even were they less rare, so far as their properties have been determined, they would not afford any advantage which may not be obtained by the use of the ordinary metals. As elementary substances, the reader will find details of their history, nature, and properties in the article CHEMISTRY.

THE STEAM-ENGINE.

AS introductory to the historical and practical details of our subject, we propose giving a few remarks on the nature and properties of steam, and of the value of the different kinds of fuel used in producing it. These being understood, the reader will be prepared to follow us when describing the steam-engine as applicable to the various purposes of the arts and manufactures, its construction, its operation, and economical management.

In connection with the theory of the steam-engine, the consideration of the nature and properties of water, which forms the grand agent in its operation, is a matter of some importance. For general remarks on this subject we beg to refer our readers to Nos. 31 and 32; proceeding to notice here the special points connected with it which have an immediate reference to our present subject.

Water is a fluid at ordinary temperatures, but may become *solid* on the one hand, or *aëriform* on the other, by changes in the amount of caloric (heat) with which it is supplied. These two remarkable changes in the condition of water occur at specific temperatures: it becomes solid at 32° Fahrenheit, and passes off in the state of vapour or steam when the temperature is raised to 212°. On the fluid being cooled down to 32°, it becomes ice—this temperature being named the *freezing-point* of water. When the temperature is increased so that the thermometer indicates 212°, or the *boiling-point*, the water becomes steam or vapour, assuming that condition in which its elastic force is applied to act as a moving power.

It is with the properties of this steam or vapour that we have now to do. The vapour of water, unlike other gaseous bodies, does not retain permanently its aëriform condition; this being alone dependent upon the continuation of the high temperature which formed it. By reducing this, the vapour ultimately assumes its former condition of water. Hence is obtained one of its valuable properties, so useful in the steam-engine, in one of its principal forms—namely, its *convertibility from the form of vapour into that of water*.

The second property in steam to be noticed is its *expansibility*—the vapour occupying 1728 times the space of that occupied by the water from which it is raised; this, however, presupposes the steam to be raised at the ordinary pressure of the atmosphere, and the boiling-point to be consequently at 212°. As with other gases, the degree of expansibility of steam is regulated by the pressure to which it is subjected. Thus with a pressure of 18 pounds on the square inch, the bulk of steam, as compared with that of the water from which it is produced, is 1411; with a pressure of 20 pounds to the inch, 1280 times; with a pressure of 25 pounds, 1043; with a pressure of 30 pounds, 880; 35 pounds, 766; 40, 679; 45, 610; and with a pressure of 50 pounds to the inch, 550: these proportions being approximative. This expansive property of steam, from which is deduced the law, that its pressure varies with its bulk, is another of the valuable properties which is taken advantage of in one modification of the modern steam-engine.

The third property of steam now to be described is that of its *elasticity*. In consequence of this property, it tends to free itself from the space in which it is confined, expanding in so doing in bulk or volume. The degree of elasticity, or the force of steam, is dependent on and regulated by the temperature under which it is raised. Thus, at the ordinary temperature of boiling water, the pressure which it exerts is, in round numbers, 15 pounds to the inch; when the temperature is increased to 250°, the elastic force is 30 pounds to the inch, or, as it is termed, steam of two atmospheres. The following tables shew the elastic force of vapour from 32° to 212°, and from 275° to 359°:

Temperature.	Force of Vapour in Inches of Mercury.
32°	·200
50	·375
80	1·00
100	1·86
150	7·42
180	15·15
200	23·64
212	30·

Temperature.	Elastic Force.	Pressure Square Inch.
275°	3 atmospheres, or	45 lbs.
307	5 "	75 "
332	7 "	105 "
351	9 "	135 "
359	10 "	150 "

From these it will be seen that the elastic force of steam increases in a much faster ratio than the temperature at which it is generated. Thus, 212° gives 15 pounds to the inch; 250° gives 30 pounds—an increase of 38° doubling the pressure.

The accompanying table gives the correspondence observed between the temperature at which the water boils, the density of the steam generated, and the force or elasticity it possesses in inches of mercury and atmospheres:

Temperature Fahrenheit.	Sp. gr., air at 60 Degrees being 1.	Pressure in Inches of a Column of Mercury.	Pressure in Pounds on the Square Inch.
212°	0·484	30·	14·7
222	0·553	35·00	17·15
233 ·80	0·687	45·00	22·05
242 ·50	0·81	52·50	25·725
250 ·20	0·915	60·00	29·4
274 ·70	1·33	90·00	44·1
320 ·60	2·5	180·00	88·2
350 ·00	3·61	270·00	132·3
450 ·00	10·75	900·00	441·

From these tables, it is apparent that there is an invariable correspondence between the force of the vapour of steam and the temperature at which it is generated; hence the one may be given as the rule of the other. For instance, if it is required to know the force with which the steam is working in any machine, the thermometer, which is preserved in a case air-tight, and introduced into the boiler where the steam is generated, will indicate the temperature of the water, or of the steam (for they are always the same; that is, at whatever temperature water boils to afford steam, the steam so produced is of the same temperature). On ascertaining, then, the temperature by a reference to the table, we find the corresponding force of the elastic vapour (the steam). An example will be sufficient to shew this most clearly:—When the thermometer stands at 212°, and steam escapes from the water, we know it is then able to support a column of mercury 30 inches high; and a column of mercury 30 inches high is equivalent to the pressure of one atmosphere. The steam, then, is of the kind called low-pressure. If, however, the temperature indicated be 250°, then opposite in the table we find 29·4 pounds pressure on the square inch, and 60 inches of mercury; but as 29·4 pounds is double the weight of the atmosphere on the square inch, and also as 60 inches

of mercury is double the height of the column which the air will support, the steam must then be acting with a force equal to two atmospheres.

Mr Tredgold gives the following rule to ascertain the elastic force of the vapour of water, in inches of mercury, at any given temperature of Fahrenheit's thermometer:—To the given temperature 100 is to be added, and the sum divided by 177. The quotient is to be raised to the sixth power, which is the force required. If, for example, the temperature be 307°; to this 100 added gives 407. This, divided by 177, gives 2·3, of which the sixth power is nearly 148, the elasticity of the vapour, in inches of mercury, almost equivalent to five atmospheres. This rule, it is to be observed, only refers to the vapour produced from pure water; when it is mixed with a considerable proportion of saline matter, as in the case of sea-water, a different divisor must be adopted, which is to be regulated by the temperature at which the water boils, for the point of boiling varies with the amount of salt in the water. Water saturated with common salt contains about $\frac{1}{3}\frac{8}{3}$ portions of that matter, and its boiling-point is about 226°. The divisor to be used in this case is 185 instead of 177, and the elastic force of the steam will then be found not to exceed 113 inches.

The following diagram illustrates an apparatus by which steam of different pressures may be raised, and the connection between the temperature indicated by the thermometer T, and the elasticity of the steam in the interior of the copper vessel *bm*, as indicated by the barometer EF, the tube of which dips into a quantity of mercury *m*, placed at the bottom of the copper vessel; *b* is a stop-cock, by closing which the pressure of the steam can be increased as required.

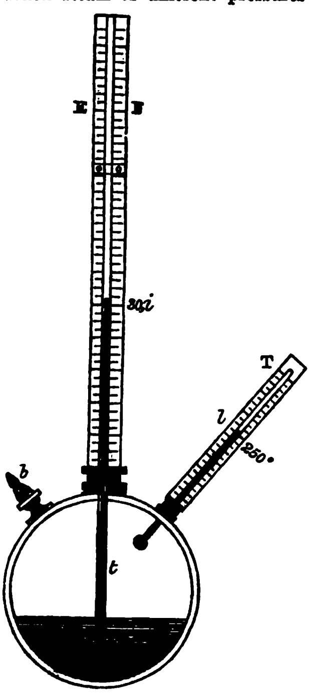


Fig. 1.

Incidental to the formation of steam, it has been observed that there is a great quantity of heat which disappears on the vapour being formed, and which cannot be discovered by the thermometer, but is again given out when the vapour returns to the state of water. The most singular and most important practical fact connected with this property is, that whatever be the temperature at which the water is boiled to form steam, the sum of that temperature, and the number of degrees of latent caloric, is always the same. Suppose the water boils at 212°, and the quantity of latent caloric absorbed be equal to 1000°, the sum of these will be exactly 1212°. But if the water boil at 112° (under diminished pressure), the latent caloric will then be 1100°, to make up the aggregate sum 1212°; and in like manner, if, under increased pressure, the water be made to boil at 312°, the quantity of latent caloric will only be 900°. Hence steam formed at a low pressure, or at the ordinary temperature of the air, does not require a different amount of fuel for its production from that required by steam generated at 100° higher, or any other temperature; for the sum of the latent and sensible heat is always the same—1212°, as measured by the thermometer of Fahrenheit. To convert, accordingly, a given weight of water into steam, the same amount of fuel is required at all temperatures.

Steam is thus seen to have four properties or qualities: its convertibility into water, by which a vacuum can be formed; its expansibility, or property by which a given quantity of steam can increase in bulk, its weight remaining the same; its elasticity, by which it is capable of returning to its original form on the cessation of any force which may act upon it; and, lastly, its latent or concealed heat, in opposition to the sensible heat indicated by the thermometer.

Steam used practically as a moving power is of two kinds—high-pressure and low-pressure. The latter is that used in condensing engines, and varies from 19 to 25 and 30 pounds on the square inch. High-pressure steam varies from 35 to 90 pounds on the square inch. We have now to trace the mechanical effect obtained by the production of steam. Steam, or vapour of water, expands, as we have before stated, into 1728 times the bulk of water; a cubic foot is just 1728 times a cubic inch: hence is derived an easy method of remembering the fact—a *cubic inch* of water converted into vapour gives a *cubic foot* of steam. The temperature being 212°, and the pressure consequently 15 pounds to the square inch, a piston of one square inch in surface, and loaded with 15 pounds, can thus be raised in a tube, which we suppose to be 1728 inches high, by the evaporation of a cubic inch of water placed in the tube below the piston: the number of inches here mentioned gives 144 feet; hence we see that the mechanical effect obtained by the evaporation of a cubic inch of water is equal to the raising of a 15 pound-weight a height of 144 feet; or, to reduce it to the usual way of stating it, 2160 pounds raised one foot high. There are 2240 pounds in a ton; hence is derived the approximative rule, that the evaporation of a cubic inch of water gives a power equal to the raising of a ton one foot high. This effect is found to be the same in all cases, no matter what the pressure is at which the steam may be raised. We have already shewn that the bulk or volume of steam depends upon the pressure; thus, steam at a pressure of 45 pounds to the square inch will occupy a space of 610 cubic inches, and would, in the case above stated, only raise the piston and weight one-third of the distance, or 48 feet; but this multiplied by the pressure will give the same result as 15 multiplied by 144.

In the condensing or low-pressure engine, as it is usually called, the mechanical effect produced by the condensation of any given quantity of steam is obviously equal to the evaporation of the same quantity of water into steam. Thus, a vessel of one cubic foot in capacity—when the piston with which it is furnished is raised to its full height—is filled with steam raised from a cubic inch of water. On the condensation of this steam, and its conversion into water, the piston will descend in the vessel pressed down with a pressure of 15 pounds to the square inch—which obviously exerts a power capable of lifting a certain amount through the aid of chains and pulleys.

From this theoretical estimate of the mechanical effect of steam, a considerable proportion must be taken for the loss by friction and other causes.

The mechanical effect obtained by the expansion of steam remains to be stated. The pressure of a gaseous fluid compressed or forced into any vessel varies with the amount of compression—where its natural bulk is compressed into half the space, the pressure is doubled; and so on. The converse of this applies where the gaseous fluid is allowed to expand itself into greater bulk. Where the space it occupies is twice its usual amount, the pressure it exerts is only half; if expanded

into three times its usual bulk, its pressure is decreased to one-third; and so on. Steam, in common with other gaseous fluids, follows this law. By cutting off the entrance of the steam into any vessel or cylinder in which a piston moves, at a point equal to half the stroke or length of the vessel, the piston is propelled through the remaining portion of the cylinder with a force gradually decreasing in proportion as the steam expands. At the end of its stroke, the steam, which originally filled one-half of the cylinder, and exerting say a force of 30 pounds on the square inch of piston, will have expanded so as to fill the whole of it; but the pressure will only be *one-half* of what it was originally. In this case, it is evident that a quantity of steam equal to half the space of cylinder has been saved; and that although the pressure exerted by the remaining half decreases as it expands, still the power it *does give out* is obtained for nothing—that is, without the expenditure of a further supply of steam. By saving steam, fuel is saved; and although the power of the engine is diminished, still in practice the saving of the fuel is greater in proportion than the diminution of the power. Hence the economical value of the expansive system of working.

This mode of using the steam expansively may be illustrated in the following manner:—If the piston is pressed by a weight of one ton, and can be raised four feet when the cylinder is supplied with steam of the ordinary pressure of one atmosphere, the same piston loaded with four tons will be raised one foot, if the cylinder be one-fourth full of steam of four atmospheres. When the steam of four atmospheres is admitted, it is cut off when the piston is raised one foot. But the piston has now received an impulse, and the steam beginning to expand under it with a gradually diminishing force, it is raised to the second foot, so that the volume of the gas is doubled, and its elasticity becomes only equal to two atmospheres. On the piston being elevated to the third foot, the volume of the steam will be trebled, and its pressure or elasticity now reduced to one atmosphere and a third. But when the piston is raised the fourth foot, the steam will have been quadrupled in volume, and the force equal to that of one atmosphere.

This principle is now much employed, and particularly in the Cornish mines, where it has been used with great success, the pressure of the steam in the pumping or drainage engines being four atmospheres. The benefit of working a steam-engine in this mode increases the earlier the steam is cut off, but not much after it is rarefied four times.

Steam cut off.	Power multiplied.
$\frac{1}{2}$	1·7
$\frac{1}{3}$	2·1
$\frac{1}{4}$	2·4
$\frac{1}{5}$	2·6
$\frac{1}{6}$	2·8
$\frac{1}{7}$	3·0
$\frac{1}{8}$	3·2

We now come to consider the relative qualities of different fuels, and the economical effects produced by their combustion. The mechanical effect produced by the combustion of a given quantity of fuel varies much according to its evaporative properties, and the arrangement and construction of the boilers and furnaces in connection with which it may be used. In ordinary cases, the quantity of water converted into steam is six or eight pounds for each pound of coal consumed. Where a cubic foot of water is converted into steam per hour, a mechanical effect equal to an estimated horse-power is obtained; to evaporate this quantity, a weight of six pounds of coal on an average of qualities is required. Hence is deduced the approximative rule, that by the combustion of six pounds of coal per hour, a mechanical effect of one horse-power is obtained. By a high degree of care taken in the construction and management of boilers and steam-engines, a much higher value can be given to fuel. In some of the Cornish engines, three pounds of coal, and in some cases 1¾ pounds, give a horse-power.

In carrying out the evaporation of water in steam-boilers, the great point to be attended to is to produce the greatest amount of heat from the smallest quantity of fuel. Charcoal, or the substance carbon, is, properly speaking, the principal ingredient in the combustible matters which are usually taken to produce heat. It constitutes the main bulk of coal, of coke, of anthracite, which is a species of natural coke, and of wood in all its varieties.

During the process of combustion, the quantity of heat which is disengaged can be precisely determined; as, for instance, by ascertaining how much of a given amount of combustible matter is required to raise the temperature of water from 32° to the boiling-point (212°).

It is here to be carefully noted, that to raise water to the boiling-point, and to convert water into steam, do not imply the same thing, though they both imply the application of heat steadily to the fluid matter. This arises from the great quantity of latent caloric which the steam requires, and which amounts, by calculation, as well as by careful experiment, nearly to 1000° of Fahrenheit; that is to say, if it takes a given time, with an equal and uniform quantity of heat, to raise water from 32° to 212° (180°), it will require that time multiplied by $5\frac{5}{9}$ to convert the water into steam. But in one period—namely, the time required to raise the water to the boiling-point—as much heat as raised the water 180° was added, and 180° multiplied by $5\frac{5}{9}$ gives exactly 1000°. It is to supply this great quantity of latent caloric that so immense an amount of coal is consumed by the steam-engine. For if one pound of the best coal raises 33·3 pounds of water from 32° to 212°, then one pound will only suffice to convert 5·5 pounds of water into steam. Or, while one pound of coal raises 33·3 pounds of water to the boiling-point, it will require about 5½ pounds more of the same kind of fuel to convert all that water into steam.

To convert the coal into those chemical compounds, during which the evolution of heat takes place, a very great proportion of air is required; for the atmospheric air contains four-fifths of its bulk of matter, which does not in any manner assist combustion. Two and a half pounds of oxygen, or nearly 30 cubic feet, are requisite for the combustion of one pound of coal; 150 cubic feet, therefore, of atmospheric air will supply this. It has, however, been found that one-third of the air which enters the furnace passes through it without directly contributing to the process of combustion, but withdraws heat; the actual amount, therefore, of air required is in round numbers about 220 cubic feet.

The results of experiments on bituminous coal go far to prove the correctness of the opinion that has long been held, that its evaporative value is equal to the evaporative value of coke produced from it. Indeed, it has been found that the work produced from coke is actually greater than that of the coal from which the coke was made. Government some time ago instituted a series of experiments in order to test the relative values of a variety of coals useful for the purposes of the steam-navy. The results were published in an elaborate report by Dr Lyon Playfair and Sir H. De la Beche, which contains a vast amount of practical information on fuel fitted for combustion in steam-engine furnaces. In this report, a table is given shewing the high economical value of coke, as compared with the bituminous coal from which it is produced. Thus, when the quantity of water evaporated by one variety of bituminous coal was 9·35 pounds, the coke from this evaporated 11·301; another quality, evaporating 9·46, gave in the shape of coke 12·554; and so on of certain qualities as now stated. Thus, one coal gave 8·86 as its economic evaporating power; its coke, 10·873: another coal, 7·47; its coke,

8·144: another quality, 8·94; its coke, 10·601. In a table given by Tredgold in his work on *Warming and Ventilating*, the superiority of coke over coal is also shewn; thus, to evaporate one cubic foot of water into steam, takes 8·4 pounds of Newcastle coal, while 7·7 pounds of coke do the same work. Should further trials bear out this economic value of coke, it will have an important bearing on the manufacture of gas, which, instead of wasting the coal from which the gas is extracted, will actually render it more valuable than before. Coke might also be made separately with profit, by saving the other products of the distillation.

Before proceeding to the practical details of the steam-engine in its various forms, we think it well to give a few historical notes, shewing the rise and progress of the invention.

It appears, by careful examination of the records of history, that the action of steam for producing motion (though not then proposed to be applied to practical purposes) was known as early as 130 years B.C. This was produced by an instrument denominated an *æolipyle*, described by Hero of Alexandria, of which a figure is annexed, and which may be considered the original of the steam-engine. The æolipyle is formed by a globular metallic vessel, which rests on pivots, at and where it can revolve with perfect facility. Two tubes proceed from this ball at right angles to the pivots, shut at the extremities, but with a small aperture at the side, whence steam may escape. The pivots are the extremities of tubes connected with a boiler below, as marked in the sketch. On the boiler being heated, steam passes by the pivot tubes, C, B, into the cylinder, from which it issues by the little aperture F at the side of the cylinder tube E. As the steam escapes, it rushes out with great force; and as it presses on the side opposite to the aperture, it forces it and the cylinder to move round in the contrary direction. One tube will suffice.

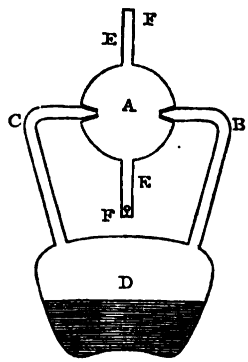


Fig. 2.

The next notice of steam-power worthy of our attention is in the seventeenth century. In the year 1663, a work was published by the Marquis of Worcester, named, in the language of that period, *A Century of the Names and Scantlings of such Inventions as at present I can call to mind to have Tried and Perfected.* The following extract, describing what he terms a 'fire waterwork,' seems distinctly to convey the idea of a steam-engine:—'An admirable and most forcible way is to drive up water by fire, not by drawing or sucking it upwards, for that must be as the philosopher calleth it, *intra sphæram activitatis*, which is best at such a distance. But this way *hath no bounder* if the vessel be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full of water, stopping and screwing up the broken end, as also the touch-hole, and making a constant fire under it; within twenty-four hours it burst, and made a great crack; so that, having a way to make my vessels so that they are strengthened by the force within them, and the one to fill after the other, I have seen the water run like a constant fountain stream forty feet high; one vessel of water, rarefied by fire, driveth up forty of cold water. And a man that tends the work is but to turn two cocks, that one vessel of water being consumed, another begins to force and refill with cold water; and so successively—the fire being tended and kept constant, which the self-same person may likewise abundantly perform in the interim between the necessity of turning the said cocks.'

In 1698, Mr, or Captain Savery, obtained a patent for a steam-engine, which was the first introduced to raise water. The principle of his plan consisted in injecting steam into a vessel connected with a vertical pipe, dipping into the water to be raised, and then condensing it by cold water, so as to form a vacuum, or, at all events, a space in which there is vapour of very feeble elastic force. By the pressure of the atmosphere, the water was then driven up until it attained a height proportionate to the pressure of the atmosphere, diminished by the force of the uncondensed vapour. By a peculiar but simple disposition of the valves, the return of the water was prevented; but as the water could not in this manner be elevated higher than twenty-six feet (sixty-four feet by force of steam), the plan was not adopted to any extent.

The next step in the improvement of the steam-engine which we have to record, is the introduction of the cylinder and piston. In the former attempts above noticed, the steam acted upon water; here, upon a solid piston moving in a cylinder. To Papin, a celebrated Frenchman, the inventor of the safety-valve and steam-digester, is due the suggestion of this great improvement. His plan was, however, very crude, and obviously incapable of practical use, inasmuch as the cylinder itself contained the water which produced the steam, which being raised, elevated the piston; the fire was then removed, and the cylinder cooling, the steam was condensed, and the piston fell. This was merely a toy, but it contained the germ of the principle which, in other hands, made the steam-engine ultimately the grand prime mover which we see it now is. In the next step which we have to record, this cylinder and piston will be seen as an important part of the mechanism. In the atmospheric engine invented by Newcomen and Cawley in the year 1713, these very important improvements may be traced—the cylinder and piston—the separate boiler—and the beam by which the mechanical force obtained was made effectual in pumping water from coal-mines; at that period the great end for which steam-power was so desiderated. The boiler B, fig. 3, is placed over a furnace; from this, a tube conveys the steam to the cylinder C, immediately connected with the boiler, the supply of steam being regulated by the valve V.

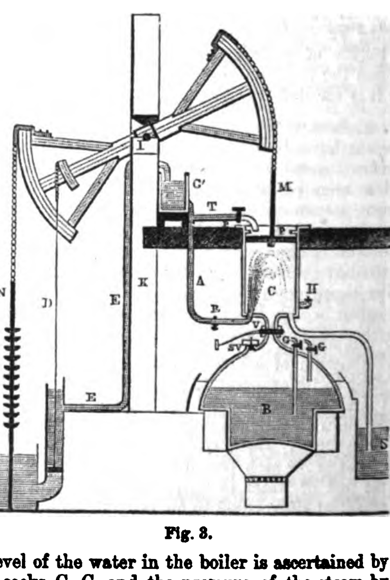


Fig. 3.

The level of the water in the boiler is ascertained by the gauge-cocks G, G, and the pressure of the steam by the safety-valve SV—these will afterwards be described. The piston P works in the cylinder C, and is kept tight

by a stream of water issuing through a pipe regulated by a stop-cock T, and supplied from a cistern C'. From the same cistern the water for condensing is supplied to the cylinder by the pipe A; the water of condensation is led from the interior of the cylinder by a pipe to a cistern S, this being placed at a considerable distance below the cylinder, in order to balance the atmospheric pressure, which would otherwise force the water up the pipe into the vacuum created in the cylinder. The air which gains access to the cylinder by the steam, is allowed to pass off through the snifting-valve H, which opens upwards. The piston-rod, M, is connected by a chain to a quadrant placed at the end of a beam, which vibrates on a centre I; the pump-rod, N, is attached in a similar manner to the other end of the beam. A second and smaller pump supplies the cistern C', through the pipe EE. The operation of the engine is as follows:—The fire being properly raised, and steam freely formed, the valve, V, is opened, to allow the entrance of the steam. The snifting-valve, H, is now forced open, and the air escapes along with the steam, until the cylinder is full of steam. The regulator-valve, V, is now shut, and the stop-cock R, on the pipe A, being opened, the cold water is injected, and condenses the steam. But as a vacuum is effected by the condensation of the steam, the pressure of the air, acting with a force equal to fifteen pounds on the square inch on the surface of the piston, carries it down to the bottom of the cylinder, and consequently raises the other end of the beam to which the pump-rod, N, is attached. In this manner the water is raised from the mine; and, by a repetition of the movements already noticed, a constant discharge of water results.

The celebrated engineer Smeaton brought this form of engine to a high degree of perfection; and Beighton of Newcastle rendered it self-acting, by introducing what is called hand-gear, by which the engine opened and closed the various valves. This was an improvement on an assemblage of strings and levers, which were introduced, it is said, by a boy named Humphrey Potter, to avoid the trouble of a personal superintendence.

Great as was the advance effected by this form of engine, it had many defects, the chief of which we now enumerate. Much steam was lost during the process of the heating of the cylinder after each condensation; for it had always at least to be raised to the temperature of the steam before the steam could, as such, continue in it, and be in any degree efficient; and, on the other hand, the cold air which followed the descent of the piston, necessarily withdrew a considerable portion of heat. By the calculations of Watt, it was estimated that *three* times as much steam was expended in this manner as would have been equal to work the engine—a loss, therefore, equal to 75 per cent. Nevertheless, this, as has been correctly observed, 'was the first really efficient steam-engine—that is, the first engine which could be applied *profitably* and *safely* to the most important purposes for which such machines were required at the time of its invention.'

The happy conception which formed the first step in the career which has immortalised the name of Watt, was that of *condensing the steam without cooling the cylinder*. After the notion of separate condensation had occurred to him, all the other details of the engine were of comparatively easy introduction. His first improvement constituted what has been termed the single-acting engine. In this form of the engine the steam was admitted only above the piston at first, the vacuum being below it. When the piston had gained the lower part of the cylinder, the communications between the steam-pipe and cylinder, and also between the condenser and cylinder, were closed; and through the medium of a tube communicating laterally, the steam which was above, diffused itself below the piston, so that on either side it was subject to an equal force. But on the other extremity of the beam there was a weight, which raised the piston up, and the steam all necessarily flowed below the piston. On the communication between the condenser and cylinder being made free, a vacuum was induced, and the steam-pipe being then opened, a rush or current of steam proceeded to the upper part of the piston, and the movements were repeated as before.

This form of engine was not by any means well suited for the purposes of communicating motion to machinery, in consequence of the inequality of its action; but it served admirably for the purpose to which it had been first applied—namely, that of raising water from mines. It is, however, in a great measure, even for that latter purpose, superseded by the double-acting engine of Watt, which we shall hereafter describe.

We now proceed to the consideration of the various parts of the modern steam-engine in its different varieties; and first as to the boiler and its appendages.

The form of boiler introduced by Watt was termed the 'wagon.' Fig. 4 shews a transverse section of this: *a* the fire-bars and ash-pit, *d* the boiler, *bb* the furnace, *c*, *c* the flues. The boiler is sometimes strengthened by stays *e*. Fig. 5 is a longitudinal section of the wagon-boiler with its appendages as arranged by Watt. These we shall hereafter

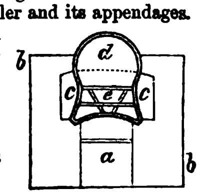


Fig. 4.

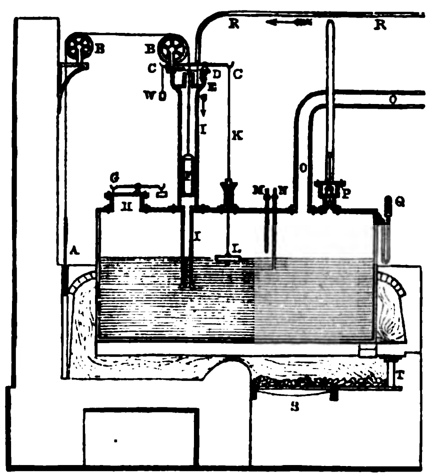


Fig. 5.

describe in detail. The wagon-boiler is now rarely used, our best authorities condemning it as unsafe, and by no means economical. The Cornish or cylindrical fluid-boiler is much used, and is considered to be safe and very economical in its operation. To admit of the system of alternate firing (see CONSUMPTION OF SMOKE, No. 31), two flues are used, as in fig. 6.—the fire-bars are situated in these flues. Fig. 7 is a longitudinal section of this

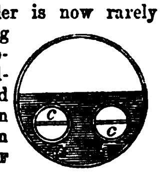


Fig. 6.

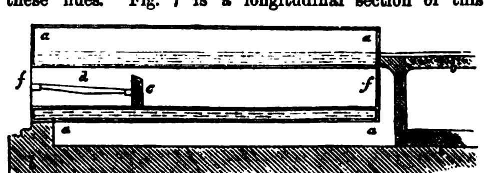


Fig. 7.

form; *aa* is the boiler, on a brick foundation *bb*; *c* the

fire-bridge, *d* the fire-bars, *f* the internal flue surrounded by water. Fig. 8 is a plan shewing the two

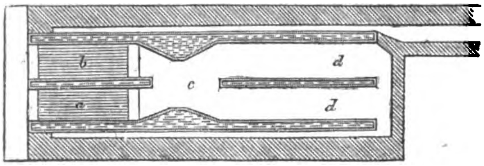


Fig. 8.

fireplaces *a*, *b*, with the mixing chamber *c*, and the two flues *d*, *d*.

The multitubular boiler, shewn in fig. 9, is one which is rapidly coming into extended use. The boiler rests on brick supports *e*, *e*, *e*; *a*, *a* the fire-bars; *b* the fire-bridge; *d* a valve for admitting air to an air-distributer *c*, passing the air to the back of the bridge, to promote combustion of the smoke. The heated air passes through a number of tubes *n*, *n*, surrounded by water, and ultimately passes off to the chimney through the smoke-box *oo*. *vv* the safety-valve, *h* the man-hole door to gain access to the interior for cleaning purposes, &c., *f* a pipe for carrying off the water and deposits, *tt* the stop-valve in the pipe leading to the engine, *x'x* the water-feed apparatus—these we shall describe hereafter. Having given the principal varieties of boilers now in use, we proceed to illustrate the appendages.

And first as to the supply of water. In Watt's boiler

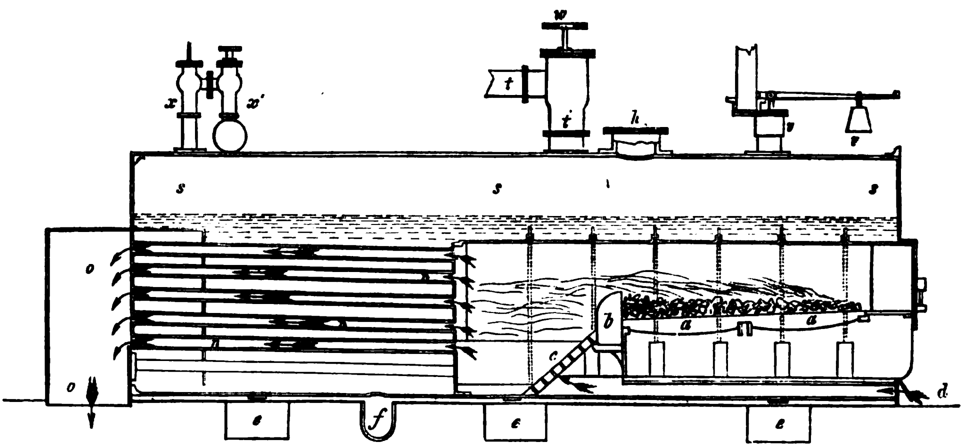


Fig. 9.

(fig. 5), the apparatus to secure this was as follows:—The cistern DE is supplied with water from the hot well of the engine. A valve is situated at the bottom of the cistern, which is made to open upwards, on the rod being raised which connects it with a lever D. This lever is so placed as to move on a fixed point at the upper part of the cistern. At one extremity of it, a small wire, K, is attached, running through a steam-tight aperture in the boiler, having a float, L, at its termination resting on the water. To counterpoise this, there is a weight, W, suspended at the other extremity of the lever connected with the cistern. As this float is balanced in the water, when it is rapidly evaporated, it will follow the water-level, and as it descends, will necessarily bring down the arm of the lever to which it was connected; the other arm will be elevated in a corresponding manner. But the valve in the feed-pipe being attached to a rod which is fixed to the lever, will be carried upwards as it is raised, and the water will pass down, until the float, being raised in a corresponding degree, will enable the other arm of the lever to which the counterpoise was attached to fall, and thereby bring down the other end of the lever, and close the valve. By this arrangement, as long as there is a sufficient supply of water from which the cistern can be filled, there will always be a sufficiency running down in a continuous stream to feed the boiler for the production of steam.

In consequence of the general adoption of the principle of expansive working of condensing steam-engines, this method of supply is now being superseded by the plan of forcing the water directly into the boiler by means of a force-pump. In connection with this, an apparatus known as the 'differential feed' is frequently used. This is illustrated in fig. 10. A pipe, *a*, is carried down within a few inches of the bottom of the boiler, *bb* is a circular chamber into which the water is forced by the pump. There are two apertures in this chamber, each supplied with a valve, as *c*, *d*, these opening upward.

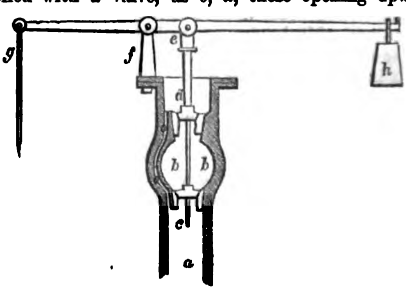


Fig. 10.

The chamber *d* communicates with the pipe *a*, and with the boiler by means of a channel or way, *oo*, in the thickness of the pipe. A lever oscillates on a standard *f*; and is connected with the valve-spindle by a rod *e*. A rod, *g*, is connected with the stone-float in the interior of the boiler (see L, fig. 5), counterpoised by a weight *h*. On the float falling, it pulls down *g*, raises *h* and the valves out of their seat; water is allowed then to pass down *c* into *a*, and from thence to the boiler. As the pressure of the steam, on the surface of the water in the boiler, might force water up the pipe *a*, and open the valve *c*, and thus allow water to pass down without any influence of the float, the small channel *oo* prevents this action. The water forced up the pipe *a* by the pressure of the steam, passes through *oo* into the chamber *d*; and pressing on the top of the valve *d* with as much force as it presses on the under side of *c*, the pressure is thus equalised. This form of feed is also applied to high-pressure boilers.

The height at which the water in the boiler stands is ascertained by two methods—the gauge-cocks and the water-gauge. The former contrivance is illustrated in fig. 5 at M, N. One pipe, N, is made long enough to reach the level at which water should be at all times, below which it should never fall. The shorter pipe, M, is taken down to the level at which steam should always be, and to which the water should never rise. Consequently one pipe, when its stop-cock is opened, should always pass steam, the other water. When N passes steam, there is too little water in the boiler; when M passes water, there is too much. The attendant adjusts the supply accordingly. The water-gauge, illustrated by fig. 11, affords an evidence of the level of the water in the boiler by inspection: *aa* is part of the front of the boiler, *bb* the level of the water; a pipe, *gd*, communicates with the steam-space of the boiler, the pipe *e* with the water-space; a glass tube, *c*, connects these two, and stop-cocks, *g* and *f*, are placed so as to cut off the connection when required. If both cocks are opened, the level of the water in *c* shews that in the boiler—the pressure in *c* being obviously the same as in the boiler. A small stop-cock placed at the lower part of the pipe *c*, allows the water which is in it to pass off, leaving the pipe empty when required. A great variety of apparatus for effecting a safe supply of water to boilers has been introduced, and many ingenious appliances to warn the attendant engineer of a deficient supply—one of the great causes of boiler-explosions.

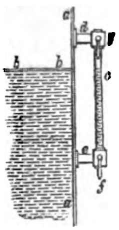


Fig. 11.

The next appliance we have to notice is the important one of the safety-valve; the duty of which is to admit of the steam's escape when it exceeds a certain pressure, and to prevent it until the pressure necessary to work the engine is obtained. An improved arrangement of valve is shewn in fig. 12: *aa* is a steam dome fixed on

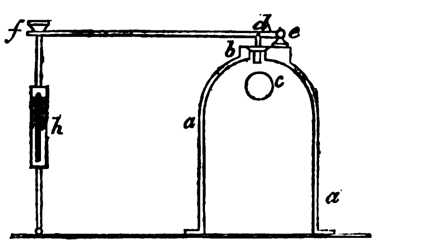


Fig. 12.

the top of the boiler, a conical brass valve, *b*, is placed in the seat steam tight; this valve is connected with a lever *df*, by a lever *d*, this being jointed to a stud *e*, fixed to the dome. The other end of the lever is pulled down by means of a spring *h*, attached to the boiler. The pressure of the spring is adjusted as desired by the nut *f*. The index of the spring shews at a glance the pressure of steam in the boiler; thus, if the nut is screwed down, depressing the end of the lever until the index points to, say 45, on the steam lifting the valve, its pressure is known to exceed 45 pounds. In the generality of cases, instead of a spring, a weight is used; this is moved along the lever according as the pressure is required, the lever being graduated. The further the weight is from the stud *e* (fig. 12), the greater the pressure. As the weight is apt to be tampered with by attendants, thus increasing or otherwise altering the pressure considered to be safe, Mr Fairbairn has introduced a plan of safety-valve, in which the weight is in the interior of the boiler, all that is visible being a small dome. The great objection to the form of conical safety-valve is the likelihood of the valve jamming or sticking in its seat. Mr Nasmyth obviates this difficulty by carrying the valve-spindle into the interior of the boiler, and loading it there with the necessary weight. To the lower part of the spindle he attaches a sheet-iron appendage, which, being acted upon by the ebullition of the water, sways to and fro continually, and, by the intervention of the spindle, keeps the valve moving in its seat, but not to such an extent as to allow of any escape of steam. The form of valve is spherical, which admits of less friction than the conical.

Although the safety-valve regulates the extent to which the pressure of the steam may go, it does not indicate the amount or degree. To do this, the apparatus termed the steam or mercurial gauge is used.

This is an iron tube B (fig. 13), bent in the shape of a U, the upper end of which, at A, is of glass, furnished with a graduated scale. Mercury is poured into the tube, and stands at the same level in both legs when the steam is not admitted to the short leg. On this being the case, the pressure makes the mercury rise in the long leg proportionate to the pressure. For each inch the mercury rises in the long leg, a pound of pressure in the boiler is indicated; but as the tube is double, an inch in the long leg is actually two inches of rise of the mercury.

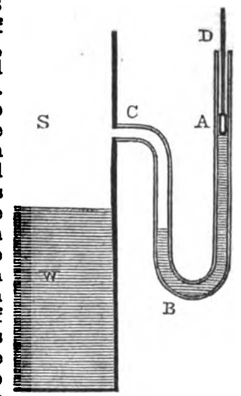


Fig. 13.

Gauges for high-pressure boilers are also used; they are generally in cases, with graduated faces.

In Watt's boiler the draught of the furnace was regulated by a float F, placed in the tube of the 'feed.' The pressure of the steam in the boiler forced the water up the tube, and with it the float F, the damper A, connected with the throat of the flue, and attached to the float by the chain passing over the pulleys R, R, also fell, and closing up the throat of the chimney, lessened the draught, and reduced the pressure of the steam. Self-acting dampers have not been very generally introduced into modern practice, the dampers being more frequently regulated by hand; a counterpoise weight, connected with the damper by chains passing over pulleys, being placed within the reach of the stoker.

The singular phenomena attendant upon the explosion of boilers have given rise to numerous theories to account for them. It is a subject still a source of much discussion amongst engineers and scientific men. It is pretty generally conceded that if all the appliances we have indicated are properly fitted up and managed, the chances of boiler-explosion will be materially lessened. The two great points, according to the eminent authority Mr Fairbairn, being the supply of water and good safety-valves, the former being, if possible, more important than the latter, especial care should be taken never to allow the flues or parts of boiler which are exposed to the action of the fire to become bare; the water should in all cases cover them. Another safety contrivance we have yet to notice is the fusible plate. This is a plate composed of a combination of metals, tin, lead, and bismuth, which melt at a temperature ranging between 280° to 750°. This plate is fixed in the upper part of the boiler, and protected from its *pressure* while exposed to its temperature. If this greatly increases, from any cause, the metal melts, and leaves an opening for the escape of the steam. From the metal melting unequally, a source of danger rather than of safety has been supposed by some to lie in this contrivance. Such an authority as Mr Fairbairn, who has the following, will surely be of some weight on the opposite side of the

question. 'In France,' says Mr Fairbairn, 'the greatest importance is attached to those fusible plates..... In this country, these alloys are not generally in use; but in this respect I think we are wrong, as boiler-explosions are not so frequent in France as in this country; and high-pressure steam, from its superior economy, is more extensively used in France than in England.' Many engineers adopt the precaution of having a hole in the lower part of the boiler, below the water-level. This is filled up tight with a plug of lead: so long as this is covered with water, the heat of the furnace does not melt it; but on becoming exposed by the evaporation of the water from want of attention to the supply, it melts, and allows the steam and water to rush out into the furnace and flues.

Steam-engines, as used in modern practice, are divided into two classes, those in which the cylinder is fixed, and those in which it is movable—that is, in which it oscillates: this latter variety, called the oscillating engine, is a very important one, and has especial bearing on marine-engine construction.

The fixed-cylinder engines, as well as the oscillating ones, are again divided into two grand classes or divisions—those in which the steam is condensed after leaving the cylinder, commonly called low-pressure, and those in which the steam, after working the piston, passes to the atmosphere, called high-pressure. The exigencies of modern practice have tended to alter this distinction of low-pressure and high-pressure engines very materially. In former times, a condensing engine always worked with low-pressure steam, now they more frequently work with steam of high-pressure than with low, since in the great majority of well-managed engines the expansive principle is put in practice. Not far from where we write, a pair of condensing-engines are working with a pressure of steam at the boiler of 75 pounds to the inch. Hence the terms condensing and non-condensing more accurately define the two classes.

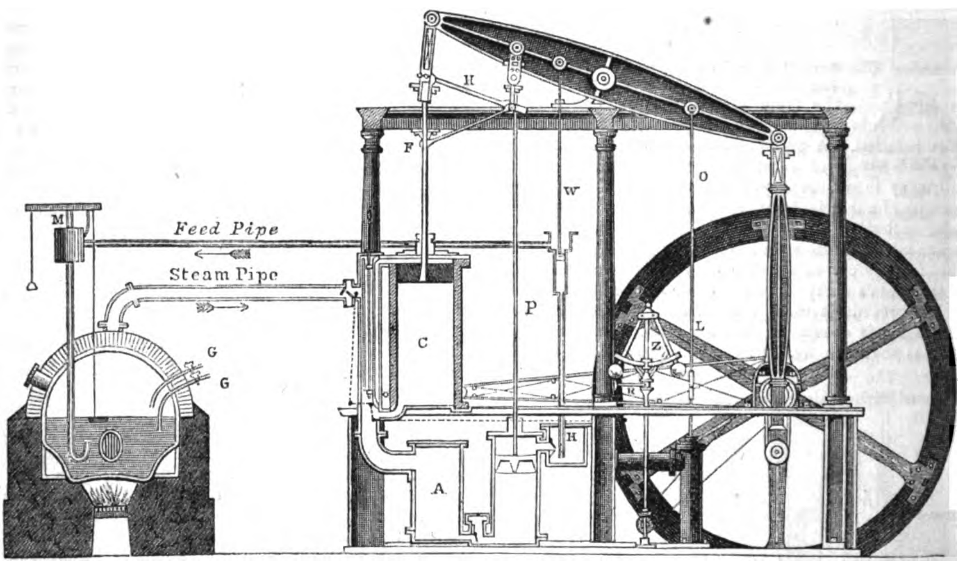


Fig. 14.

The form of engine illustrated in fig. 14 is that of Watt's double-acting engine, of which the following is a general description. The steam from the boiler passes along the steam-pipe to the valve-casing, from whence it is 'distributed,' as it is termed, to the upper and under sides of the piston, producing its alternate up-and-down motion in the cylinder C. After working the piston, the steam passes to the condenser A, where it is condensed by coming in contact with a jet of cold water—omitted to be shewn in the diagram. From the condenser, the water of condensation, together with the air which obtains admission through the steam, and which, if allowed to accumulate, would ultimately prevent the engine working, is drawn off by the air-pump, and delivered to the hot-well H. An arrangement of valves prevents the water from returning to the air-pump from the cistern, and also prevents the water in the air-pump which may remain therein at the bottom from being again forced into the condenser on the down-stroke of the air-pump piston. The condenser and air-pump are placed in a cistern filled with cold water, supplied by the pump OL. The injection-water to the condenser is supplied from the cistern, and is regulated by a stop-valve. The piston-rod is connected with the end of the working or walking beam, and is kept parallel by a beautiful arrangement of levers termed the parallel motion. The other end of the beam is connected to the upper end of the connecting-rod, which at its lower end is attached to the crank. To equalise the motion, a heavy wheel, the fly-wheel, is keyed on to the crank-shaft. In the revolution of the crank there are two points, called the dead-points, at both of which the power of the engine has no effect in causing any revolution. These points obtain, when the piston is at the termination of the up-and-down stroke; at the former, the only effect of the engine is by means of the connecting-rod to press down the crank; while at the latter the effect is to pull it out of its bearings. By the momentum acquired by the fly-wheel while receiving the full power of the engine, the crank is carried past its dead-points. Where the engine is required to act with great uniformity, the irregular action of the engine even with a fly-wheel is much felt, and various contrivances have been adopted to equalise the motion; these we have not space to describe. Having now given a general idea of the arrangements of the engine, we proceed to describe the parts and movements in detail.

The Cylinder and the distribution of the steam to it

by means of valves, termed slide-valves.—These are of three varieties—the long D, the short D, and the three-ported. There are other forms of valves, as the equilibrium, puppet valves, &c., but the slide-valve is the form generally used. We shall describe the long D valve generally adopted in condensing engines, as illustrated by fig. 14. Fig. 15 is a diagram illustrative of the position of the valve when the piston, *d*, is at the bottom of its stroke.* The valve is in the form of half a tube with flat portions *a*, *a* (fig. 16), made very smooth, and which work steam-tight in the face of the cylinder; the back, *bb*, is hollow; and stuffing is applied at top and bottom, which works against the back of the valve-casing; by this means the valve works steam-tight in the casing. The steam which fills the space of the cylinder above the piston is escaping through the upper steam-port *f*, down the hollow *bb*, at the back of the valve, and thence to the condenser by the pipe *h*. The steam gains admission to the hollow space in front of the valve through the throttle-valve *g*; the steam from the boiler gaining admission to this space—and is seen passing downwards through the lower steam-port *e*, to the under side of the piston, which it forces to the top of the cylinder; during its upward motion, the valve is moved into the position shewn in fig. 17. The steam below the piston is now passing to the condenser by the lower steam-port, which is left uncovered; and the steam is passing to the upper steam-port *c*. The valve is moved by the rod *b'*, which is connected with the eccentric rod as shewn by fig. 18. In

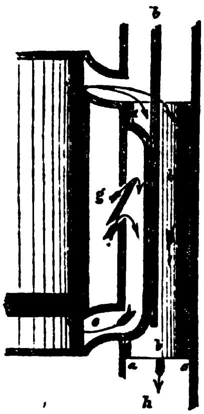


Fig. 15.

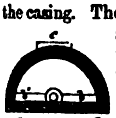


Fig. 16.

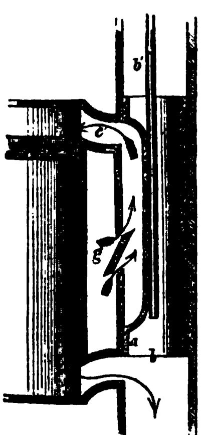


Fig. 17.

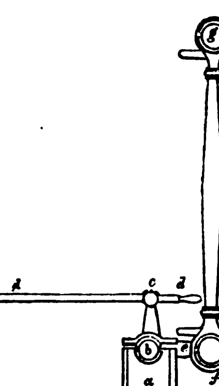


Fig. 18.

the number on MECHANICS, we have explained the action of the *eccentric*, and shewn how the circular motion is changed into any required amount of rectilineal motion. In fig. 18, *dd* is the eccentric rod, which gives a to-and-fro motion of the lever *cb*, which works in the plummet-block *a* (see MECHANICS). The other end of the bell-crank lever, *e*, is jointed to the end, *f*, of a side-lever, the upper

* The length of the stroke of an engine implies the space moved through by the piston in its ascent or descent, and consequently, during one complete revolution of the crank-shaft, the piston moves through twice the length of the stroke.

end of which is jointed to the extremity of the valve rod cross-head. A similar arrangement of levers, as in fig. 18, is at the other side of the engine; the shaft of the bell-crank lever, *be*, reaching across the breadth of the engine. This shaft is termed the rocking-shaft or weigh-shaft. By this arrangement, the eccentric causes the cross-head of the valve-rod to work up and down; and by this means the valve which is attached to the centre of the cross-head by the rod *b* (fig. 17), is moved in the valve-casing as required.

The Piston.—The old method in use for keeping the piston steam-tight was the wrapping of hemp tightly round it, a space being left between the upper and lower disks into which the hemp was placed. This plan is now rarely adopted, metallic pistons being almost universally used. Fig. 19 illustrates a form used; *b*, *b* are two rings of metal cut into segments; these are pressed outward by means of a spring *c*; *aa* the part into which the piston-rod is fixed. A simple metallic piston is made by having two rings of metal, out of which a part is cut; the two rings are placed one above another, the cut part of the one opposite to the solid part of the other. The two rings are placed between two disks the same diameter as the inside of cylinder, and compressed so as to bring the edges of the cut together; in this state, they are put into the cylinder; and the tendency of the rings to expand and to widen the distance between the cut edges, keeps them always pressed against the interior of the cylinder.

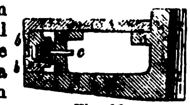


Fig. 19.

The Cylinder-cover Stuffing-box.—The piston-rod, *bb*

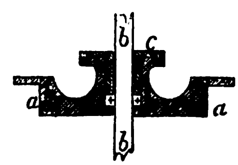


Fig. 20.

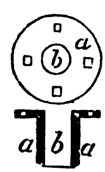


Fig. 21.

(fig. 20), works steam-tight in the aperture in the cylinder-cover, by what is called a stuffing-box. An annular space is left in the cover, and into this a gland, *aa* (fig. 21), is placed; the size of the aperture, *b*, in this is as near as possible equal to the diameter of piston-rod *bb*. A packing of hemp is forced into the parts marked * * in fig. 20; and the gland pressing on this, keeps it tight up to the piston-rod. The gland is secured to the cylinder-cover by means of bolts and nuts.

The Parallel Motion.—In the atmospheric engine of Newcomen, and the single-acting engine of Watt, the piston-rod was connected with the working-beam by means of a chain; the piston pulling the end of the beam down, and the counterpoise on the beam pulling the piston up. When, however, the steam-engine was applied to the production of circular motion, the piston-rod had to act upon the beam by pushing as well as pulling, the chain was therefore no longer eligible. As the end of the beam described part of a circle, and the piston-rod a right line, it was necessary, in making the connection between them, to arrange so as to maintain the parallelism of the piston-rod. This Watt effected by means of his parallel motion, which the reader will find illustrated in the number on MECHANICS.

The Governor and Throttle-valve.—The supply of steam to the cylinder is regulated by a valve called the throttle-valve. This is a disk of metal fitted to the interior of the steam-pipe, and moving on a horizontal axis. The edges of this plate are made angular, so as to fit steam-tight against the pipe when closed, its position being at an angle to the length of the pipe. When the valve is horizontal, the full supply of steam is admitted; as its position approaches the vertical, the supply is correspondingly lessened. In some small engines, this valve is

operated upon by hand; but in the majority, the engine affects it according to its own necessities. The mechanism so long used in water-mills, known as the governor, was applied by Watt for this purpose. The nature of this piece of mechanism will be understood by the following fig. A spindle or upright rod, with a pulley on its lower

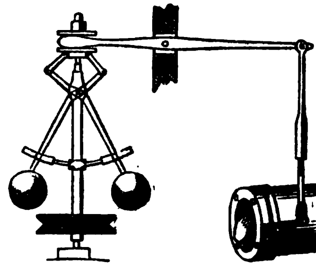


Fig. 22.

part by which it is moved, receiving motion through a strap attached to the shaft or axle, has two balls, which revolve along with it. These balls, by the centrifugal force generated by the revolution of the spindle, fly out from, or approach to the spindle according to the rate of revolution; the balls being attached to jointed levers moving in a curved guide fixed to the spindle. The levers act upon a movable boss, which is embraced by a forked lever acting upon the handle of the throttle-valve. As the speed of the engine increases, and the rotation of the governor becomes more rapid, the balls fly outwards, and extending the lower levers, raise the boss, and depresses the end of the lever of the throttle-valve. This being closed more or less, the quantity of steam admitted to the cylinder is diminished; the speed of the engine is lessened; the governor rotates less rapidly; the balls approach the spindle, pulling down the boss, and raising the lever of the throttle-valve, and admitting more steam to the cylinder. These changes are continually going on while the engine is in operation.

This apparatus is only comparatively efficient, the great drawbacks attendant upon its use being—first, the time which elapses before the governor can act upon the throttle-valve—the levers taking time to assume their relative position; secondly, the rapidity with which the valve can be opened to 'full,' or closed to 'shut,' there being too little gradation between these two points. Various contrivances have therefore been brought out, which have for their aim, that nice and immediate regulation of the valve, so necessary to bring about the regularity of action and the freedom from oscillation in the working of the engine desiderated for many processes in the arts and manufactures. From the want of immediate control over the valve, engines often run away, as it is termed, breaking many of the parts, and doing much damage; the immediate cause generally being the sudden throwing off of the work of the engine, as the stoppage of a number of looms, &c., by the breaking of a shaft. A form of throttle-valve or steam-valve has been recently introduced, and found very effective; there are two valves of the same form and species as the conical safety-valve—these being on the same spindle, one above another. A very little rise and fall is required; as the two valves need only to be opened to half the extent to which one would be required, comparatively slight action of the governor is necessary.

To obtain a knowledge of the condition of the vacuum in the condenser, a vacuum-gauge is used. This is a tube connected with the interior of the condenser, and passing through a cup containing mercury. The tube is continued upwards nearly to the end, and finished with a glass-tube closed at the end, the lower end of which dips into the mercury. The vacuum in the glass-tube is the same as that in the condenser. The atmospheric air pressing on the mercury, forces it up into the interior of the glass-tube, the rise being directly proportioned to the difference between the pressure of the *uncondensed vapour* in the condenser and the pressure of the atmosphere; a graduated scale, attached to the glass-tube, gives the degree of vacuum in the condenser.

For various details not here specified, as crank, connecting-rod, plummet-blocks, &c., we refer the reader to the number on MECHANICS, where he will find them fully illustrated. We now proceed to the description of the high-pressure engine. We have already adverted to the distinction between this class and that of condensing engines.

As the condenser, cold-water-pump, air-pump, cistern, &c., are dispensed with in the high-pressure engine, it is rendered more compact, and consequently less space is taken up by it. So early as 1720, Leupold produced a high-pressure engine; but the first invention which came into extensive use was the engine of Messrs Trevithick and Vivian, constructed by them in 1802. Since that period they have come into very general use, being much cheaper than condensing engines; and we may add, that the steam, after working the engine, instead of being projected into the atmosphere, may be used for warming premises, heating water for baths, and similar purposes.

The forms of high-pressure engines are various. The crank-overhead engine is the simplest form, and is very effective; engines with the crank under the cylinder are also much used; and a small size of this form, represented in fig. 23, is much used for driving small coffee-mills in grocers' shops. Their cost varies from £20 to £50, without the boiler. The most complex of all is the beam high-pressure engine. In general appearance it is much like the double-acting engine of Watt; but of course there is no condenser and its associated apparatus. High-pressure horizontal engines, the whole machinery of which lies horizontally, are coming much into use. Brunel's oblique-acting engine, we believe, is a very efficient form of high-pressure.

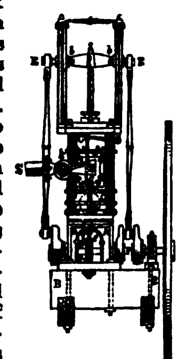


Fig. 23.

In fig. 24 we give a vertical section of a crank-overhead engine. The steam is admitted from the boiler to the steam or valve chest *bb*; in this chest the valve works, sliding steam-tight against the valve face of the cylinder *aa*. There are three steam-ports—one of these leading to the bottom, the other to the top of the cylinder; the third, marked *o* in the drawing, leads to the exhaust-pipe. The valve covers two of these ports at the same time, one of which is always the exhaust-port. When the valve covers the upper steam-port, and the exhaust-port, the steam rushes from the space of the cylinder above the piston, down the port, and through the exhaust-port to the atmosphere; at the same time the steam is rushing from the steam-chest down the lower port to the under side of the piston *vv*, which it presses upwards. On the piston *vv* reaching the top of the cylinder *aa*, the valve is changed to the position of the diagram to the right in fig. 26. The valve *a'* covers the exhaust-port *b'*, and the lower steam-port *d*; the steam is rushing from the space below the piston *vv*, through the port *d*, and to the atmosphere through the exhaust *b'*. The movement of the valve up and down is produced by the revolution of the eccentric and eccentric-rod *j, j* (fig. 24), the play of the valve being double the distance of the working-centre of the eccentric from its true centre. The revolution of the crank-shaft, *gq*, is effected by the crank *h*, and connecting-rod *g*; this latter being fastened

to the end of the piston-rod by what is called a *piston cross-head.* The parallelism of the piston is preserved

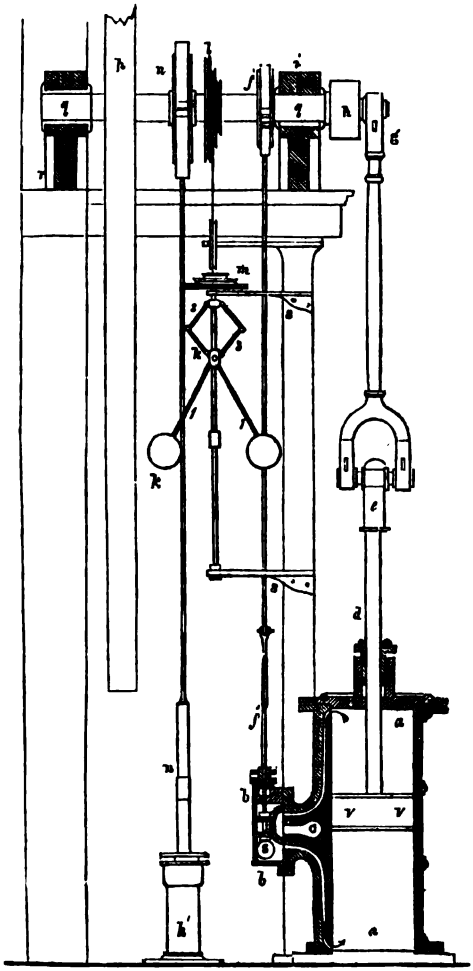


Fig. 24.

during its reciprocation by the cross-head sliding between two parallel guides, which are bolted to the upright framing that supports the crank and fly-wheel shaft. The crank-shaft is supported on bearings *q, q, r* (fig. 24).—The water is supplied to the boiler by the force-pump *h'*, which is worked by the rod and eccentric *m*.—The supply of steam is regulated by the governor *kk*. This is supported by two brackets 8, 8, bolted to the upright framing. A three-motion pulley, *l*, is fixed on the fly-wheel shaft, and a corresponding pulley on the upper termination of the governor-spindle. As the planes of motion of these pulleys are in opposite directions, a guide-pulley, *m*, is used to take the motion of the pulley on the shaft to that of the governor. As the governor is made to rotate rapidly, the balls *k*, by virtue of the centrifugal force, fly outwards, extending the arms or levers 1, 1, and depressing those marked 3, 3. Those are fixed by movable joints to a brass bush, which slides up and down on the spindle. The periphery of this bush—which is provided with projecting ruffs or collars—is embraced by the fork of a lever, which is connected with the throttle-valve fixed to the steam-pipe (fig. 15). The valve is thus closed—the admission of steam to the cylinder is lessened—the velocity of the engine is diminished—the governor rotates more slowly—the balls fall, lowering the arms 1, 1, and raising the arms 3, 3; and thus again opening the throttle-valve, allows the steam to enter the cylinder.

In fig. 25 we shew the method of attaching the eccentric pump-rod *mm* (fig. 24) to the pump-plunger; *aa* is the upper part of the pump-plunger; it is forked at its termination, the two forks *bb* being circular, as shewn at *ab'*. Holes are bored in these forks, through which the pin *e* passes, and which is secured by the cottar or key, *f*, being driven through the key-seat made at the end of *e*. Previous to inserting and securing the pin *e*, the end *cc'* of the eccentric-rod is inserted between the forks *bb*, so as to make the aperture made in it, as *d*, coincide with the apertures in *bb*; the pin, *e*, is then driven in, and secures them together.

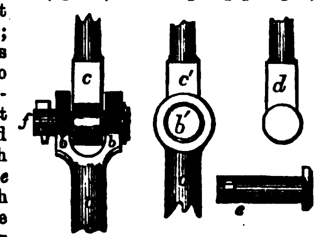


Fig. 25.

As there is greater danger to be apprehended from the use of high-pressure steam, the boilers of the engines are generally provided with two safety-valves—one locked up from the control of the engineer. The boilers are generally not so complex in their arrangements as those of low-pressure; indeed, in all their arrangements simplicity is the leading characteristic. They perform their work well, do not require such close attention, and with a reasonable degree of care, no danger of explosion need be apprehended. It may be mentioned here that locomotive engines for road and railway are all on the high-pressure system.

In high-pressure engines the steam is distributed to the cylinder by means of the three-ported valve. Fig. 26 shews the valve in the two positions, at the termination

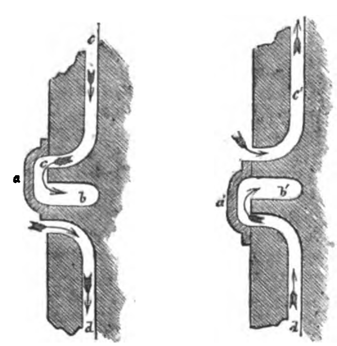


Fig. 26.

of the up-and-down stroke. The valve-face (see fig. 27), placed at the back of the cylinder, is planed perfectly true, and made very smooth. There are three ports in this: *c* leads to the upper part of the cylinder; *d* to the lower part; and *b*, the exhaust-port, leads to the external atmosphere. The form of valve is shewn at *a* and *a'* in fig. 26; the hollow part of which covers two of the ports, one of which is always the exhaust-port, the other the upper and lower ports alternately. The valve works within a casing, to which the steam is supplied; and is kept in close contact with the valve-face by means of a spring, or, instead of this, the pressure of the steam. In fig. 26, the sketch to the left hand illustrates the position of the valve when the piston is at the bottom of its stroke; the steam from the valve-casing, or steam-chest, as it is also called, is passing through the lower port and channel *d*, to the under side

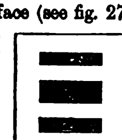


Fig. 27.

of the piston, while the steam from the cylinder space above the piston is passing out at the upper port *c*; but as this is covered by the valve, it is forced to pass out through the exhaust-port to the atmosphere. The sketch to the right shews the position of valve when the piston is at the upper part of the cylinder.

In high-pressure engines, the expansion principle is carried out by what is called expansion gear, which acts upon the steam-valve so as to cut off the steam at any desired part of its stroke. The forms of expansion gear are very numerous; we shall only describe a very simple arrangement. In fig. 28, let *a* be the steam-chest, *b* the exhaust-port, *c* the lower, and *d* the upper steam-port; a supplementary steam-chest *e*, with another valve called the 'cut-off,' is connected with the ordinary steam-chest *a*. The steam is supplied in the first instance to the supplementary steam-chest *e*; and any quantity can be admitted to the cylinder; that is, the supply cut off at any desired point of the stroke by merely adjusting the valve in the supplementary steam-chest, so that it will close the passage to the main steam-chest at any desired part of the stroke. This is effected by varying the throw of the eccentric which works the valve in the steam-chest *e*, this variation being adjusted by a simple mechanism which we have not space to illustrate here. Two eccentrics in this arrangement are thus required, the one which works the cylinder-valve in the steam-chest, *a*, being invariable in its throw.

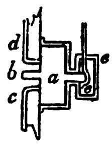


Fig. 28.

Steam is also used expansively in high-pressure engines by giving what is termed lap to the valve. This may be simply described as giving an extra length to that part of the valve which closes the ports—this lengthening being towards the steam-side; that is, the part towards the inside of steam-chest. Thus, in fig. 29, let *a* be the valve, *b* the port; if the valve is lengthened by a portion, as *c* (not shaded), it is evident that the port will be so much the sooner closed as the addition *c* is longer or shorter. To work effectually, the port should be fully closed when the piston has performed two-thirds of the stroke.

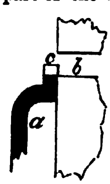


Fig. 29.

Another term which the reader may often meet with is the lead of the valve—what this is, we shall endeavour to explain. The action of the eccentric is such that its slowest speed is during the first portion of its throw; the consequence of this is, that the valve leaves a port very slowly at first, the progress of the steam to the exhaust-port being consequently retarded. As the steam, if allowed to remain long in the cylinder, would oppose the progress of the piston, and rob it of some portion of its power, it is necessary to arrange so that the steam will leave the cylinder as soon as possible after the completion of the stroke. The amount of valve-opening at this point is termed the lead of the valve, and is obtained by fixing the eccentric on the shaft more or less out of the ordinary line of centres.

A system of applying the expansive method of working to condensing-beam engines which may be deficient in power, now being extensively used, is that of having a supplementary steam-cylinder, connected with the beam in the opposite side of the beam-centre to that at which the usual cylinder is attached. The supplementary cylinder is supplied with steam at high-pressure, which, after working the piston, passes off to the usual or condensing cylinder, from which it passes to the condenser. This plan, introduced by Mr M'Naught of Glasgow, is found to be very efficient.

In order to convert the rectilineal motion of the piston into the circular one of the fly-wheel, with the intervention of as few movable parts as possible, a class of engines known as direct acting have been introduced. Nearly all high-pressure engines are on this principle, the object being to transmit the power of the piston immediately to the crank-shaft. A very common method of doing this is illustrated in fig. 30; a cross-head, *cc*, attached to the piston-rod, sliding between two parallel guides *a*, *a*, bolted to the framing. The lower end of the connecting-rod, *d*, is jointed to the cross-head, and the upper to the crank-pin (for method of making these attachments, see number on MECHANICS) of the crank *e*. There is much loss of power from friction by this method, which, however, can be reduced by careful workmanship. There is also a strain exerted on the piston-rod, in consequence of the thrust and pull of the crank—this is, however, in a measure obviated by lengthening the connecting-rod.

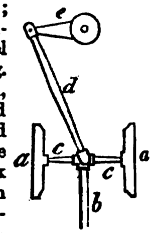


Fig. 30.

The best and simplest form of direct-acting engine is that known as the oscillating. As the end of the cylinder describes an arc of a circle—from the cylinder vibrating on centres in the direction of its length—the reciprocating motion of the piston-rod adapts itself to the position of the crank, and thus enables the piston-rod to be attached at once to the crank-pin without any connecting-rod being required. The centres on which the cylinder oscillates are termed trunnions, being hollow pipes, one of which is the supply, and the other the exhaust steam-pipe. The valve is worked by a curved link attached to the eccentric-rod, and so arranged as to be free from the effect of the cylinder oscillation. In some recently introduced oscillating engines of small power, the vibration of the cylinder is made to work the valve, thus further reducing the moving parts. In the section on marine engines, we give an illustration of an oscillating engine adapted to a steam-vessel.

To obviate certain supposed disadvantages of the oscillating engine, as the oval wearing of the cylinder from its constant movement, another form of direct-acting engine has been introduced, called the 'trunk-engine,' by which a fixed cylinder is obtained, and immediate connection of the piston-rod and crank. Fig. 31 illustrates this form: *aa* is the fixed cylinder; to the piston *b*, a hollow trunk, *cc*, is fixed, working through a stuffing-box. The diameter of this trunk is such that it admits of the vibration from side to side of the connecting-rod equal to the throw right and left of the crank *e*. The connecting-rod is attached to the piston at one end, and to the crank-pin at the other. The cylinder in this form requires to be of greater diameter than in ordinary engines, in order to get the amount of piston-surface; the steam acting only on what may be termed a ring of piston formed between the outside of the trunk and the interior of the cylinder.

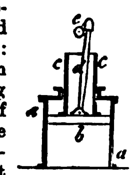


Fig. 31.

Before describing the locomotive and marine engines, we shall present a few remarks on another class not yet alluded to, vastly different in the principle of arrangement from those already described. The class referred to is the rotatory. In this form of engine, the cylinder, piston, crank, and fly-wheel are all dispensed with; and a series of chambers or cavities, supplied with valves and traps, revolving round or turning with a central shaft, constitute the engine. As its name imports, the motion derived from the steam traversing these chambers is at once circular or rotatory, no reciprocating motion being produced; and in this lies the chief merit of the invention. Engines of this kind admit of being made very simple, free from complex arrangements, and their power can at once be applied without the intervention of other machinery. The varieties of rotatory engines patented are very numerous; but, whether from any inherent error in their principle, amount of friction, or from some other cause, few of them have come into anything like extensive use. The simplest form of all

is that introduced by Mr Ruthven of Edinburgh. It is the same in principle as the æolipyle of Hero; and we believe the engines fitted up by this gentleman have given considerable satisfaction. Their use is not, however, extending.

Locomotive Engines.

The form of engine adapted to the railway differs from those already described, these being stationary or fixed in large vessels, while here the smallest bulk possible is essentially required, at the same time as little weight as convenient. Accordingly, we find that in the arrangement of these engines, all that apparatus is rejected which is intended for condensation, and therefore high-pressure steam is used.

In the arrangement or disposition of the parts of the boiler and engine, there are certain peculiarities which require to be described. It is necessary to premise, that the great object is to effect as speedily as possible the conversion of a large quantity of water into vapour; this is accomplished by arranging the boiler in a peculiar manner. It is not one large mass, as in the marine boiler, or land boiler, with a great quantity of water in the centre, but an oblong cylinder, through which are disposed a vast number of brass tubes of a cylindrical shape, amounting to about ninety in number, arranged horizontally. These tubes communicate with the furnace, and the heated air passes through them as it proceeds to the chimney, in which manner an immense quantity of the caloric is applied to assist in the evaporation of the water; so that the boiler might, nevertheless, be considered merely the same as the common one, but with the chimney subdivided into an immense number of small tubes passing through it to the large vent-hole or grand chimney. These tubes were suggested by Mr Booth, secretary of the Liverpool and Manchester Railway, and improved upon by Mr R. Stephenson, and constituted a great advance in the efficiency of the locomotive steam-engine.

In the sketch, fig. 33, is given a general exterior view of a locomotive, and in fig. 34 a longitudinal section of the apparatus. The boiler is seen forming the great bulk of the engine; its form is cylindrical, being about three feet in diameter, and eight in length. The numerous tubes, as they proceed through this part of the apparatus, are seen in transverse section in fig. 32, and longitudinal section, fig. 34. At the front of the engine is the smoke-box, terminating in the chimney above; and below, there is the steam-tube, and the cylinder and piston, which lie horizontally. At the back of the engine is the fire-box, almost completely surrounded by water, and immediately behind this is the railed space P on which the engineer stands. On the upper surface of the engine, proceeding from the hind part forwards, there is the steam-whistle X, by which notice is given of the approach of the engine. A little anterior to it is the man-hole, by which the boiler can be cleaned, and such repairs made as are requisite. Still further forwards, we arrive successively at the two valves V′, V, by which the safety of the boiler is secured. The first, V′, is always under the control of the engineer; but the second, nearer the chimney, V, is loaded higher, but completely shut up. A round spherical eminence, B, is then perceived immediately behind the chimney, called the *separator*, in which the steam gathers before it is conveyed by the tubes to the cylinder. The cylinders (two in number) are placed below the chimney, and lie immediately before the front wheels (A, fig. 34), and the steam passes to them by the steam-pipe S, whence, after moving the pistons, it escapes into the chimney. The reason why this tube rises so high in the large chamber is, that no water may descend to the cylinder, which might likely arise from the agitation the water suffers from the motion. At the point where the steam-tube in the hot-air chamber meets the connecting-pipe with the boiler, a regulator is placed, for increasing or diminishing the flow of steam.

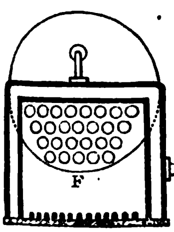


Fig. 32.

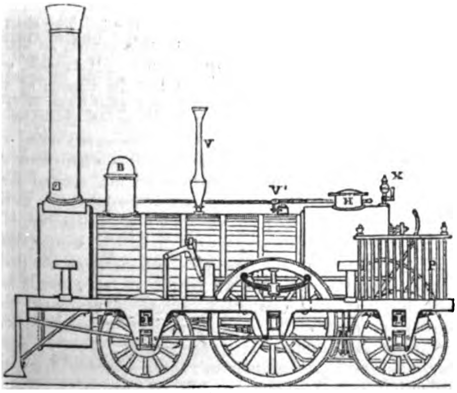


Fig. 33.

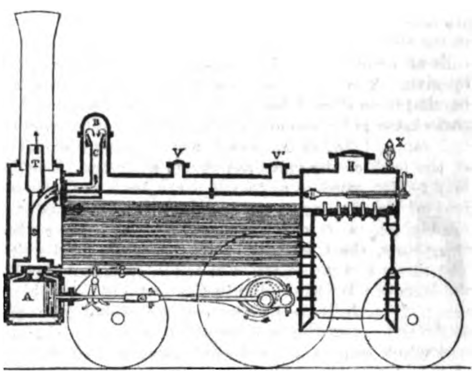


Fig. 34.

The steam, as it escapes from the cylinder by two pipes, meets in the common tube, and rushing upwards into the chimney, is in part condensed, and mainly contributes to the draught of the chimney, which otherwise would be totally inefficient to work the fire.

From the great number of the tubes which fill up the boiler, the locomotive engine is not attended with much danger in bursting; for these tubes being weak, compared with the external casing of the boiler, yield readily on any unusual increase of the elastic force of the vapour; the consequence is, that the fire is put out gradually. When one yields, a plug of wood is introduced, which is generally sufficient till the end of the *run*, or till arrival at the next station.

The size of the steam-cylinder is about twelve inches in diameter, and eighteen inches' stroke. The driving-wheels are usually six feet diameter; and some of ten feet diameter have been tried on the Great Western Railway. Three cylinder engines of great power have been introduced by Mr Stephenson, their speed being upwards of seventy miles an hour!

The engine is always attended by a tender, in which the coke and water are conveyed. The mode in which the different coaches are arranged may be seen in the number on INLAND CONVEYANCE, where a train is figured with the engine and tender.

The power of a locomotive is estimated by the quantity of water which the boiler can convert into steam within a given time. Between seventy and eighty cubic feet is

the average amount per hour; but in the Bristol railway, so much as 200 cubic feet are evaporated within the same time. The quantity of fuel consumed in Stephenson's engine is about ¼ lb. for every ton per mile.

The mechanism for effecting the backward as well as forward movement of the locomotive was formerly very complicated. The reversing gear is now, however, very much simplified by the introduction of the 'link-motion' of Mr Stephenson. Two eccentrics are fixed in the crank-shaft, one of which gives the forward, the other the backward motion of the locomotive. The ends of the eccentric rods *a*, *b* (C), fig. 35, are jointed to centres at the

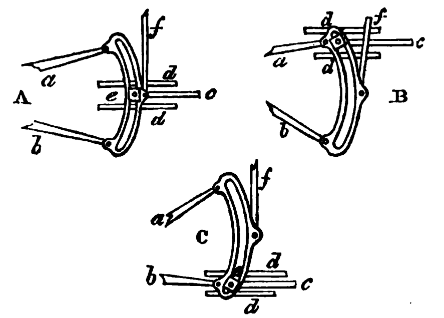


Fig. 35.

ends of a curved link, in the centre of which is a slot or opening. The valve-rod cross-head slides between two parallel faces *d*, and has a bush at its extremity, which slides between the slot of the link. By means of a lever, the link can be lifted or depressed, thus altering the position of the bush of the valve-rod in the slot: thus, the link may be depressed so as to make the bush at the lowest part of the slot, as at C; or raised so as to make it at the highest, as B; or when placed midway between these two points, the bush will be in the centre of the link. The throw of the eccentrics, *a* and *b*, being equal, when the bush of the valve-rod is in the centre of the link, the action is such that the two eccentrics neutralise each other, and no motion is imparted to the valve-rod; the only effect being to cause the link to vibrate on the bush as a centre. But when the link is raised by the lever, *f*, into the position B, the valve-rod is receiving the full power of the eccentric *a*, which may be called the forward eccentric, and the locomotive moves forward. When it is required to move backward, the link is depressed into the position C, when the valve-rod receives the full force of the backward eccentric *b*. It is evident that this apparatus is capable of being used for expansive working, the amount of throw of the valve being obviously capable of a large amount of variation between the position shewn in C and those in B and A. Expansive gear on this principle is much used.

A few historical notes on this department may not be deemed amiss in this place. The first practical locomotive for working on a line of rails (see INLAND CONVEYANCE) was that patented by Richard Trevithick in the year 1804. The railway on which it ran was at the colliery of Merthyr Tydvil, in Wales. Many of the arrangements and appliances of the modern locomotive are to be met with in this, its earliest form. One of the principal features of the locomotive of the present day—the blast-pipe by which the waste steam admitted to the chimney increased the draught—was used in Trevithick's engine.

It was, however, to the genius of the celebrated George Stephenson that the modern locomotive owed its existence. Others, doubtless, lent important aid in perfecting the mechanical details, but without the admirable inventions of Stephenson in connection with railways, the locomotive could never have arrived at its present efficiency. 'That the modern locomotive,' says Mr Scott Russell, 'could not subsist without the wrought-iron rail, and its multifarious appendages of chains, keys, locks, sleepers, switches, crossings, sidings, and turn-tables, is too evident to need proof. Without the smoothness of the rail, the engine would be jolted to pieces; and without the easy motion which it gives, the engine could not be made to draw a sufficiently profitable load to pay; and further, unless made of wrought iron, it would be impossible to attain the high speed of the locomotive without imminent danger. It therefore appears that the continuous wrought-iron railway and the locomotive engine were inventions intimately related to each other, and each a condition of each other's success. To Stephenson we are indebted for the chief features of both.'

In 1814, Stephenson, being pecuniarily assisted by Lord Ravensworth of Killingworth Colliery, constructed a locomotive which was tried on a tramway at the above colliery. This was subsequently improved, and tried at other places; but, in spite of the exertions of Stephenson to introduce them into use at various collieries, the mechanism was not sufficiently well arranged to render them economical and efficient.

The opening of the Manchester and Liverpool Railway, the engineer of which was Mr Stephenson, gave him another opportunity of bringing out an efficient locomotive, worthy of the new field of its operations. The result was the awarding of the prize of £500 for the best locomotive to the *Rocket*, the engine entered by Stephenson for the grand prize. This engine, which, with its own weight alone, traversed the railway at a speed of twenty-nine miles, created an interest in the new power which has never since then ceased to exist, and which, by directing the attention of such able mechanicians as Hackworth (to whom the locomotive owes so much), Hawthorn, and Fairbairn, resulted in establishing that wonder of modern times, railway-travelling.

Marine Engine.

In the steam-engines employed in the navigation of vessels, there are certain modifications which it is requisite here to notice.

The most striking peculiarity is the position of the beam in British steamers, which, instead of being placed above, is situated below, chiefly with the view of saving room, and is not single, but two, one at either side of the cylinder. To the upper portion of the piston-rod there is a cross-bar, which is placed transversely across the cylinder, at right angles to the long axis of the ship, or from starboard to larboard, in nautical language. From the extremities of this transverse bar, rods stretch down, connected interiorly to the termination of the beams, moving on pivots at both their connections with the cross-head and beams. The other extremities of the beams are attached to a cross-piece, on the centre of which the rod is fixed by which the crank is worked. The shaft of the paddles is firmly connected to this crank, so that it is worked along with the rod. In small vessels, only one engine is usually employed; but in vessels of considerable tonnage there are two, and their action is so

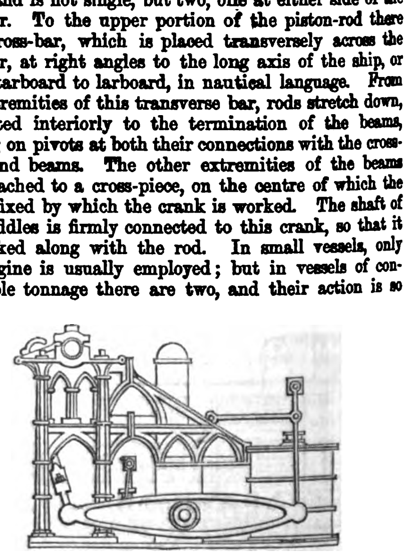


Fig. 36.

adjusted, that while the one is at its fullest strain, the other is in the reverse condition. In this manner the

motion of the wheels is preserved uniform and equal. These forms of engine are usually called condensing, the steam being worked at high-pressure, and then condensed, a result which is very readily accomplished, in consequence of the abundance of water.

Fig. 36 is a side elevation of a side-lever marine engine.

To avoid the great waste of room which the use of a side-lever engine involves, a great variety of direct-action engines have been introduced. By far the most efficient of these, according to good authority, is the oscillating engine; it takes up little space, and is economical in operation. Fig. 37 shews the application of this form to a marine engine. The trunk-engine has been also applied to marine-navigation.

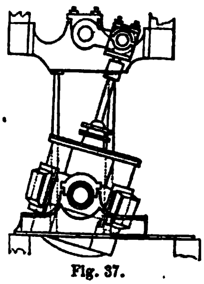


Fig. 37.

Boilers are differently arranged in steam-boats from those on land. In fig. 38 we give a diagram illustration of a form in common use. *a* is the fire-door, *b* the fire-bars, *c* the fire-bridge; the flame and smoke pass up by the space *d*, and return along the tubes *e*, *e*, to the chimney in the front of the boiler. Two of these boilers are placed back to back, by which arrangement a large amount of heating-surface is obtained in comparatively small space. It will be observed that the steam and water space is obtained rather by adding to the height than to the length, as in land boilers. A species of boiler, called the vertical, is being introduced into marine engines; in this, the boiler is of great height and small diameter; the furnace is situated at the lowest part, and the flame and smoke pass to the chimney flue through a series of vertical tubes surrounded with water.

There is a peculiarity in the arrangement of marine boilers, which it is necessary here to point out; this consists in the process of *blowing out*, as it is technically named. In sea-water there is a considerable quantity of saline matter, about 3 per cent., which, accumulating in the boiler, not only retards the process of boiling, but is apt to give rise to explosions. To obviate these imperfections, hot water is permitted to escape freely from the boiler at stated intervals, and as the discharge takes place from the interior surface, the greater portion of the saline matter is carried off. In this mode, a very serious obstacle was effectually removed. This was not done but at a considerable expense, the loss being estimated at nearly 1-54th part by Mr Tredgold; for it is apparent that an immense quantity of heat must have been lost in the warm water employed for this purpose, and not subsequently converted into steam. After all, the plan is only partially effective, as a solid incrustation remains on the bottom of the boiler so hard as frequently to break the shovels employed in its removal. This incrustation is the cause of much waste, for, from its bad conducting-power, the bottom of the boiler is often heated to redness before the required amount of steam is produced, thus causing not only loss of fuel, but rapid wearing of the boiler-plates.

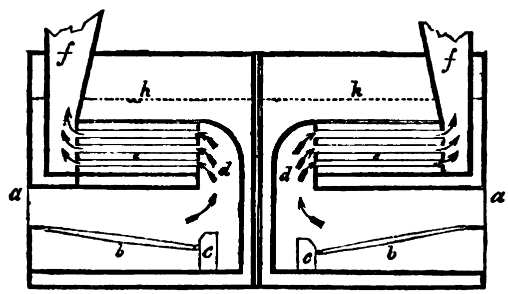


Fig. 38.

A very ingenious method has been invented by Messieurs Maudsley and Field, which preserves a uniform standard of the quantity of salt in the water of marine steam-boilers. This is effected by means of pumps, called *brine-pumps*, which are worked by the engine, and remove from the boiler the strong solution of salt and water. These pumps discharge as much salt, combined with the small quantity of water, as the feed-pumps supply to the boiler, so that the quantity of salt remains almost always the same. Further, before this hot brine is discharged into the sea, it passes through a tube included in another, which is the feed-pipe supplying the boiler from the sea, so that the greater amount of its caloric is imparted to the water, and it is reduced to nearly 100° before it is thrown out.

If the steam can be condensed merely by the application of cold water to the outside of the vessel containing it, it is evident that a boiler might be filled with pure fresh water on leaving port, and this water be converted into steam, back again into water, a second time into steam, and so on in succession, without ever coming in contact with salt. This has been effected by Mr Samuel Hall, who is the patentee of several improvements in connection with marine engines. His condenser consists of a flat vessel, in the bottom of which are a number of small apertures, and from these pipes in tubes are led to another similar flat vessel. Both vessels are air-tight. Into the top vessel the steam to be condensed is admitted, and passing through the tubes which are immersed in cold sea-water, it is perfectly condensed on reaching the under vessel, from which the newly formed water is drawn off by an air-pump. As the cold sea-water becomes heated, it is pumped off, and a fresh supply admitted. This invention, though severely tested, and found efficient, has not come into the extended use at one time anticipated for it. A condenser on the same principle has been introduced and economically worked on board of one of the Collins line of Atlantic steamers; it is known as Pirsson's.

The paddle-wheel by which the steam-vessel is propelled has undergone many modifications, for in the common mode in which the flat boards or float-boards are disposed, they both enter the water obliquely and leave it obliquely, occasioning a considerable loss of power; for it is apparent that their greatest effect must be when they are nearly in a vertical position. The complex nature of several of these wheels prevents their general employment.

The most important modification of the propelling apparatus is what is termed the *Archimedean Screw*, patented a few years ago by Mr F. P. Smith, and now very generally adopted. Vessels fitted up with screw-propellers present no unseemly paddle-boxes, are not

so liable to be damaged by collisions or by shot, and are as swift and easily managed as those propelled by the old paddles. The screw is formed by radial arms or blades, twisted, as it were, round a central iron axis. The screw thus formed is fixed parallel with the keel, at the stern of the vessel, below the water, and consequently out of sight. A variety of forms of the screw have been patented, chiefly differing as to the *pitch* or angle at which the blades are fixed on the axis. For sea-going vessels, the screw will soon, in all likelihood, be the only mode of propulsion adopted, as its advantages, either alone or as an adjunct to ordinary sailing, are numerous and decided.

In Great Britain, the engines adopted are those called *condensing*, and they usually work with a pressure of about 40 pounds on the square inch. In America, the high-pressure engine is generally used; and Stevenson states he was in a vessel on the Ohio where the common pressure used was 138 pounds on the square inch!

In estimating the work capable of being performed by a steam-engine, two methods are open for use—the nominal and the effective horse-power. The first is exceedingly unsatisfactory, and should be confined only to imply size. Mr Bourne's rule for finding the nominal power of an engine is as follows:—'Multiply the square of the diameter of the cylinder in inches by the cube root of the stroke in feet, and divide the product by 47; the quotient is the number of nominal horse-power of the engine.'

An important point necessary to be known in calculating the effective power of an engine, is the mean pressure in the cylinder during the stroke. This is obtained by the use of the instrument known as the indicator.

The *indicator* is a piece of mechanism devised by Watt, by means of which the force of the steam, and the state of exhaustion in the cylinder, are known at the different periods of the stroke of the piston. It is a small cylinder, 8 inches long and 1¾ inch in diameter, communicating directly with the cylinder, and supplied with a piston. If the force of the steam in the cylinder exceeds the pressure of the atmosphere, the piston of the indicator then rises, and if it be less, is depressed. A tracer is connected with the indicator, by which a curve is drawn on paper, indicating the variations occurring in the pressure of the steam, and from this the mean pressure is calculated. This instrument is now much used, as the only satisfactory method of knowing the working capabilities of a steam-engine. As the stethoscope to the medical man, so is the indicator to the engineer.

Different values have been given of the power of a horse;* but that generally adopted is, that it can raise a weight of 33,000 pounds one foot per minute, and therefore a steam-engine capable of executing that work is rated at 1 horse-power. On a railway, this power is considered equal to transport 400 tons one mile per day; or a horse draws 200 pounds at the rate of 2½ miles in an hour, continuously, over a pulley. The evaporation of a cubic inch of water, when converted into steam, affords a mechanical force capable of raising a ton one foot high. Fifteen cubic inches of water, therefore, when converted into steam, are equal to the power of one horse per minute, or 900 cubic inches per hour for each horse-power.

To evaporate this, from seven to twelve pounds of fuel are required in the same time (one hour); but in marine engines, the quantity consumed is about eight pounds, the proportion of fuel they consume being as two to three compared with other engines.

* The *medium* power of the horse is rated at 22,000 pounds raised one foot per minute; but 33,000 is the standard applied by engineers to the steam-engine.

Engineers possess rules for calculating the elastic force of steam and power of engines. The following may give an idea of the method of calculation:

To find the power of an engine, multiply double the length of the stroke by the number of strokes per minute, and we get the velocity of the piston per minute. If the engine works expansively, the mean effective pressure must be found. Multiply the square of the cylinder's diameter in inches by the mean effective pressure on the piston in pounds on the square inch, and by the velocity of the piston; point off three figures, and divide the product by 42, and the quotient will express the number of horse-power. Let the diameter of the cylinder be 36 inches, the length of stroke 4 feet, the number of strokes per minute 24, and the mean effective pressure on the piston 4 pounds per square inch, then

8 Feet × 24 = 192 per minute.

```
Diameter,          36
                   36
                  ---
                  216
                 108
                 ----
                 1296
Mean pressure,      4 lbs.
                 ----
                 5184
Velocity,         192
                -----
                10368
               46656
               5184
             --------
          42)995328(23·7 horse-power.
             84
             ---
             155
             126
             ---
             293
```

In connection with the working of engines, there is another term used, that of duty; it is frequently used as synonymous with the horse-power of an engine; the terms, however, are essentially distinct. By duty is meant the quantity of work done by the consumption of a certain quantity of fuel, time being left out of the calculation. In engines used for the purposes of manufactures, or for navigation, it is difficult to calculate exactly the amount of resistance which the machine encounters; but where employed for pumping water, their performance is more easily determined. The highest duty performed by an engine in Cornwall, at Wheal Hope Mine, was raising nearly 47,000,000 pounds one foot high by the combustion of one bushel of coal. Another engine at St Austell raised 95,000,000 pounds one foot high by one bushel of coal. This enormous mechanical effect was so unusual, that doubts arose as to the correctness of the report; and in the presence of a number of witnesses, the engine was again tried, when the result was, that it raised 125,500,000 pounds one foot high by the consumption of one bushel of coal.

Of the steam-power at present employed in Great Britain, it is almost impossible to form an accurate estimate; statisticians, however, reckon it as equal to about 2,000,000 horse-power—an amount of animal force which could never, in reality, be brought into full operation without extensive derangement of our whole economic system. It is difficult, indeed, to form an adequate conception of the advantages already resulting from the use of the steam-engine, still more to imagine those that are yet to result from its perfection and more extended employment. We have only to look around us to see its mighty influences visible on all hands. Navigation, travelling, automatic factory-labour, printing, mining, and a hundred other arts, have been brought to their present state only by means of this wonderful agent. In its adaptation to mills and factories, steam is doubtless more costly than water-power; but being independent of situation or seasons, it is in general circumstances preferable. Its placid steadiness, and the ease with which it may be managed, are also great recommendations in its favour. As a motive-power in the industrial arts, steam takes the precedence of all others; and, viewing it as an economiser of labour and time, it must be assuredly pronounced as the greatest of modern mechanical contributors to human progress and comfort.

CIVIL ENGINEERING.

CIVIL ENGINEERING has been defined as the 'science of construction.' In this sense it deals with the designing and execution of all works, machines as well as structures; but its popular signification is much more limited. While the designing and execution of civil and domestic structures occupy the attention of the architect (see ARCHITECTURE); and machines that of the practical mechanic (see MECHANICS—PRACTICAL MACHINERY); the designing, and construction of roads, canals, railways, harbours, piers, docks, bridges, and the supply of water to, and the drainage of towns, are understood to be the special province of the civil engineer. It is to a notice of the principal features of those works which have so materially ministered to the social and political greatness of our country, that the present article is devoted. Of necessity, the limited space at our disposal will render our notices very brief; we can only point out the principal features of the various constructions, leaving altogether untouched the principles and theories on which they depend. The following general statement of the subjects with which the civil engineer should be conversant, will shew the reader that there are few professions which demand such a varied and extensive preliminary study, independent altogether of the time to be expended in acquiring a knowledge of actual practice.

Previous to entering the office of a civil engineer to acquire a knowledge of the practice of the art, the student should be thoroughly conversant with the following branches of science: Natural philosophy, including in this term the properties of matter, motion, and forces; mechanics, elements of mechanism; hydrostatics, hydraulics, pneumatics; practical mathematics, geometry; geology; mineralogy; mechanical drawing; and the various kinds of projection used in the preparation of working-drawings. To these may be added, as useful, a knowledge of meteorology, physical geography, architecture, and chemistry (see those subjects). On entering the office, and commencing the practice of his profession, the young student should avail himself of every opportunity of thoroughly investigating the application of those principles or theories to actual constructions, and to note carefully those modifications of practice induced by its various contingencies. In addition to those general sciences, he requires a particular knowledge of what may be called 'special studies'—as, surveying and levelling in all their branches; the construction of plans and working-drawings from data obtained by these surveys; and the drawing up of specifications and making out estimates of various works to be performed. The nature and properties of the various *building materials* should next occupy his attention; as stone, brick, wood, and the various metals, mortars, cements, paints. In regard to these, he will require to know the strains which they are capable of supporting; their durability, and the means of increasing it; and the most economical and quickest methods of making them available for the purposes to which they are to be applied. In connection with this department, the best modes of arranging the materials, and the calculations by which the sizes and forms of beams are ascertained, will also engage his attention. The theory and practice of masonry will next come under his notice, embracing the various methods adopted in raising safe and durable structures, and proportioning the forms and dimensions of their various components. In this department, the following are the principal points: Foundation—in ordinary soil, in wet or marshy soils, in water; enclosing-walls, retaining-walls, counter-forts, relieving-arches. Under the head of carpentry, the student will be called upon to investigate the general principles and theory of framing, and the methods adopted in practice in constructing the joints of framed work; and to calculate the direction and force of the strains to which certain beams will be subjected, and to proportion the sizes thereto. From this somewhat arbitrary arrangement of the branches of study to which the civil engineer is required to devote himself, will be gathered some notion of the labour involved in the actual practice of the art. We now proceed to notice the more prominent features of the several operations that the civil engineer has to direct, taking the subjects in the following order: Bridges—stone, iron, and suspension; Roads, Canals, Railways, Marine Engineering—comprising roadsteads, breakwaters, harbours, docks, the protection of sea-coasts, and river improvements; Sanitary Engineering, embracing supply of water to, and drainage of towns.

BRIDGES.

Before commencing the construction of a bridge, a variety of circumstances have to be considered by the engineer. As regards its position, in most cases very little latitude is allowed; where the choice is left to the engineer, he should be careful to select a site where easy approaches and good foundations for the structure can be obtained. The nature of the water-way will have to be carefully surveyed; soundings and borings being taken to ascertain the contour of the bed, and the nature of the strata underneath. In deciding upon the kind of bridge to be constructed, the engineer must be guided by two great considerations: 1. The keeping of the water-way clear for the passage of accumulated waters during floods, and, in the case of a navigable river, for the passage of vessels; 2. The avoiding of unnecessary contraction of the stream, so as to create currents which will exercise a prejudicial effect upon the banks of the river or the foundations of the piers. To aid him in his decision on the latter point, he must repeatedly test the velocity of the current at points, above and below the site of the bridge, in its various conditions, whether in times of floods or otherwise, deducing from his observations the velocity which the water will assume when passing between the piers of his intended structure. Having satisfied himself on all these points, the engineer proceeds to set out the line of bridge, and to apportion the number of *bays* or intervals into which the water-way is to be divided, and the form and dimensions of the arches. As regards the number of bays, the rule is, that their number should be odd, thereby causing less obstruction to the current by the absence of the central pier, which an even number of bays would render necessary. Gently flowing currents may have the bays narrower than those of quickly flowing ones. Arches are of different forms—the *semicircular*, *elliptical*, and *segmental*. An arch consists of the following parts (see fig. 1): The line 1, 2 is called the *springing-line; bc*, the *span;* the distance of *a* from the line *bc*, the *rise;* the inner curve, *bac*, the *intrados;* the outer curve is called the *extrados; d*, the *keystone; e, e*, the *voussoirs*, or ring-courses; *f, f*, the abutments, of which the upper stones are called the *impost* or *springing courses*. The *crown* of the arch is at *a*. A bridge is said to be on

the level when the arches are all equal in size and the springing-line horizontal.

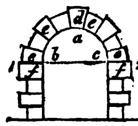
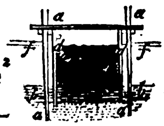




Fig. 1. Fig. 2. Fig. 3.

The construction of the piers and abutments from which the arches are to spring, next demands the attention of the engineer; and in connection with this, the most important point is to obtain a good and unyielding foundation. It is here that generally all his resources and skill are called into full play, as at this point the great difficulties of all large undertakings are met with. Where a rock or rocks can be made available, the matter is comparatively easy; but where the soil is soft and yielding, a variety of appliances are called into requisition. A very common method of constructing the foundations of piers, when these are under water, is by erecting what is called a *cofferdam*. Fig. 2 illustrates a section of this contrivance. A series of main piles, *a*, *a*, are driven into the soil, *bb*, enclosing the space on which the foundation is to be built; a row of inner piles, termed *sheeting-piles*, *d*, *d*, are driven into the interior of *a*, *a*, the space between the rows of piles being filled with clay puddling to make the cofferdam water-tight; the water is then pumped out, and the excavation for the foundation commences. The thickness of the piers is determined by the span of the arches, the height up to the springing-line, and the nature of the material of which these are to be constructed. They should be made as narrow as is consistent with the strength required to support the superstructure, so that the water-way may not be unduly contracted and currents formed, which would scour out the bed of the stream, and undermine the foundation of the piers. The thickness at the springing-line should not be less than twice the depth of the *voussoirs*, but if greater thickness is desired, the piers may be made hollow; this gives greater lightness, with strength sufficient to resist the vertical pressure of the arch. Any excess of load over this, only tends to exert a prejudicial pressure on the foundations of the pier. To preserve the bed of the stream around and between the piers, it is not an unusual practice to cover the surface with stones, thrown loosely in, of sufficient weight to resist the current. The *starlings* or *cut-waters* are the extremities of the piers just above the foundation, and the office of which is to divide the stream, without causing the formation of currents, and to guard the masonry of the foundation from the force of the water, floating bodies, &c. The best form is understood to be that of a semi-ellipse. Fig. 3 is a very usual shape. The arch-stones, or voussoirs, are supported till the keystone is put in, by a framing or *centre*. This consists of a number of vertical frames, called *trusses* or *ribs*, the outer surface of which is cut to the exact form of the intrados of the arch. The stones or voussoirs do not rest immediately upon this, but upon a series of timbers placed transversely, and called *bolsters*. In fig. 4, *a*, *a* are the back-pieces; *c*, *c*, the bolsters; *b*, *b*, the supports. When the keystone is put in, the centres are *struck*—that is, taken out. This is effected by striking out a series of wedges, on which they rest, so that the arch may be allowed gradually to settle; when this is done, the centres are quite removed, and the operation is complete. Into the architectural details—the cornice, &c.—we cannot here enter.

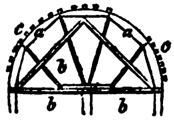


Fig. 4.

Iron Bridges.—In iron bridges the metal used is either *cast* or *malleable*, and in some cases a combination of both is adopted. The most celebrated example of a cast-iron bridge is that built over the Thames at Southwark. In this, 'each arch consists of eight ribs, and each rib is formed of fifteen pieces, which are of such depth that the rib is six feet deep at the crown, and eight feet deep at the springing. The metal is two and a half inches thick in the middle, and four and a quarter inches at the top and bottom of the ribs. The ribs are connected transversely by cast-iron tie-braces of the same depth as the ribs, but open in the centre of each; and in the diagonal direction, the ribs are connected by another series of ribs, so that each arch consists of a series of hollow masses or voussoirs, similar to those of stone-bridges. The whole of the segmental castings forming each arch, as well as the transverse and diagonal tie-braces, are kept in their places by dovetailed sockets, and long cast-iron wedges.' Bridges constructed in this way possess all the peculiarities of the stone-bridge. A materially different arrangement is that of the *girder-bridge*, on the same principle as a flooring-beam laid from wall to wall of a house. This form is much used for railways, the depth being so comparatively trifling as to make it peculiarly adapted for carrying the railway across roads or streams at a limited height above their surface. The full extent of bearing to which cast-iron girders are considered safe is forty feet; but by having a combination of wrought-iron tie-bars with the girders, a span of seventy feet has been crossed. This combination is not considered safe, and is not much used. The most generally adopted method in *wrought iron* is the *tubular girder*, invented by Mr William Fairbairn of Manchester. In this structure, the plates of metal are riveted together by means of what the inventor calls *chain-riveting*. Wrought iron being less able to bear compression than extension, the upper part of the tubular girder, when wide spans have to be crossed, is formed with rectangular cells, two or more in number. The forms in which malleable iron is applied to bridge-construction are various, and have formed the subject of numerous patents. In the wrought-iron tubular bow-bridge of Mr Harrison, the roadway is supported by an arched tube of iron, which rises above it, the *chord* of this arch being also formed of a tube, and the two being connected by a series of iron bars and braces. When used for railway purposes, there are three of those arched tubes placed parallel to one another, one dividing the *up*-and-*down* lines. The most celebrated instance in which wrought iron has been used, is that of the Britannia tubular bridge on the Chester and Holyhead Railway.

Suspension-Bridges.—In those, the roadway is suspended by vertical chains, connected with other chains stretched across the river or opening. From the principle on which the structure depends, all vertical strains are resolved into tensions in the direction of the curve; the adaptation of the materials, therefore, to the strains to which they are subjected can be more accurately determined, and much of the dead or unproductive weight, unavoidable in bridges on the arch principle, dispensed with. From the manner of construction, repairs are also easily carried out. The permanency of suspension-bridges is, however, liable to be endangered from the variations of form induced by changes of temperature, and from undulations caused by the traffic and the action of gales of wind. In fig. 5 we give the usual arrangement of a suspension-bridge: *b*, the roadway, suspended by vertical chains from the curved chains, *c*, *c*; these are made to rest upon *iron saddles* supported in the towers, *a*, *a*, and

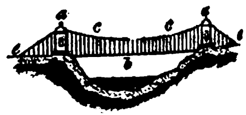


Fig. 5.

led down in the direction of *ee*, and firmly fixed into anchoring masses in the ground. The curves, *c*, *c*, may be formed of one chain or of several, and these may be either round or flat; flat bars are the most generally used. They are put together in the form of long links, connected together by bolts and plates; the bars forming each link being placed side by side, the suspension-bars for supporting the roadway may be either round or flat, and jointed in two or more lengths, to allow of their accommodating themselves to the motion of the bridge. Instead of iron-bars, wire-cables are much advocated by some engineers—a number of wires being placed side by side, so as to assume a cylindrical form, and kept together by an exterior wire. To the foot of the suspending-chains, cross-bearers are connected by stirrup-pieces; on these, planks are laid to form the roadway. Diagonal ties are generally placed between the cross-bearers. These, with trussed parapets above the roadway, and in some cases below it, prevent, to a considerable degree, the undulations caused by winds, &c. In connection with the erection of the Hungerford Suspension Bridge, many improvements were introduced; for a full account of these, see Mr Law's *Civil Engineering* (Weale).

ROADS.

When the construction of a road has been decided upon, the first duty of the engineer is to collect information to guide him in determining the best route it should take; in order not only that it may be constructed as level as practicable, and as economically, but also that it may afford facilities of communication in its route to as many towns and villages as possible, without interfering materially with the main object, which is the connection of the two extremities by as straight a line as can be obtained. This information is generally got by going over the district, and, with the aid of a good map, noting the number and situation of rivers, other roads, &c., the direction of the valleys and rising ground, and the general geological features. This general survey enables him to decide upon two or more routes which appear to him likely to be beneficial. These he surveys, and levels carefully, taking, wherever necessary, what are termed *cross-sections*, so that he can ascertain from the sections thus obtained whether any deviation from the proposed line would be advantageous. Noticing carefully the peculiarities of the *trial-lines*, he decides upon the line to be followed, which is then staked out on the ground by driving wood stakes, which mark the *centre line* of the intended road. The line thus marked out, is again carefully levelled; and from the data obtained, a section is constructed which shews the exact contour or outline of the undulating surface. From this the engineer is able to decide as to the exact line of surface the road is to have when constructed; which he endeavours so to arrange, that it may be as level throughout as possible, and the adjoining cuttings and embankments balance each other; so that the earth obtained from the former may serve to construct the latter. In the chapter on the plans and sections of railways, in the present number, the reader will find much that is applicable to the present subject.

As to the amount of ascent or descent admissible, it is generally restricted to from one inch in a yard to, at most, one inch in a foot. In order to obtain ascents not exceeding these, it is necessary, in our uneven country, to wind up a hill, instead of going directly over it. Along the side of a hill, is considered the most advantageous ground upon which a road can be constructed, provided the hill is not too steep; because what is taken from the upper side, serves to form the embankment on the lower side.

The junction of one road with another requires a little attention: it should always be made at right angles, if possible. All engineers agree that plantations of trees should not be made close to roads, as they prevent the exposure to sun and wind, which is necessary to keep the roads in a dry state; but the distance from the sides where trees cease to have a prejudicial effect, depends on the elevation of the country, the soil, the breadth and inclination of the road, as well as its direction. An elevated situation is always more exposed to winds than a level or hollow. A broad winding road has chances of the direct influence of the sun and wind, according to the obliquity of its angles; a road running north and south, though planted closely on both sides, will enjoy the sun during a part of every day in the year; one running east and west, planted on the south side with trees forty feet high or more, will enjoy no sun during the winter months.

In addition to levels, the points to be considered in laying out a road are—1. The breadth; 2. The form or *section*; and 3. The construction and material of the road.

1. The width of the road is regulated partly by the requirements of the traffic, and is partly a matter of taste and convenience, but it should not be less than thirty-three feet, to allow a free passage of vehicles in different directions. On all the good roads in Britain near towns, a side foot-path, protected by a curb-stone, is added to the ordinary breadth.

2. The section or form of the road is a disputed point among engineers: generally it is convex—the convexity, however, being comparatively slight. Mr Walker recommends it to be as flat as is consistent with good drainage. In most localities, the convexity will rarely exceed four inches—that is, the middle should be four inches higher than the sides. An idea of a perfect road may be formed from a frozen canal, where flatness, smoothness, and hardness are combined. Roads cannot be made with all of these perfections, but they should always be kept in view; for the nearer we approach to this standard, the less will be the draught. Macadam says, roads should be made as flat as possible. 'Where a road is made flat,' he says, 'people will not follow the middle of it, as they do when it is made quite convex, which is the only place where carriages can run upright, by which means three furrows are made by the horses and the wheels, and the water continually stands there; and I think that more water actually stands upon a very convex road, than on one which is reasonably flat.'

As the best form, Mr Law recommends the section to be constructed by two lines inclined from the side to the centre, at the rate of 1 in 30, these being united at the crown of the road by a segment of a circle described by a radius of ninety feet.

3. *Construction.*—There are two methods in use, very diverse in character, the one introduced by Telford, the other by Macadam. In that of the former, it is considered essential to have a firm, hard, and dry foundation, on which to place the road-materials; in that of the latter, it is immaterial whether the substratum is hard or soft—indeed, Macadam stated that he rather preferred a 'soft one to a hard one.' The point is a disputed one among engineers, each plan having its strenuous advocates; it is right, however, to state, that in this country the opinion is most favourable to Telford's plan, while that of French engineers is in favour of Macadam's.

Previous to laying down the upper material of the road, it is necessary to carry out plans for draining—a matter of the greatest importance. To insure this being effectually done, a series of trenches should be cut across the line of road, the sides of which should slope outwards, as in fig. 6, at *aa*; the trenches should have an

Fig. 6.

Fig. 7.

inclination from the centre to the sides of the road,

and a communication with the side-ditches. A tubular drain, *b*, or drain formed of tiles or stones, is placed in the bottom of the trench. Where roads are drained in this manner, the side-paths may be drained by having a slope towards the road, at the side of which an open channel is made, into which the surface-water runs; from this channel it is led by a small vertical drain, covered with a grating, and which communicates with the cross-drain. In fig. 7 we give a section of a road: *b*, the road; *a*, *a*, the fences at the side; *d*, *e*, the ditches into which the drain, *f*, discharges; *h*, the drain of the path. When the ground is of a very soft, wet, or clayey nature, this plan of drainage is the most effectual. A simpler plan is shewn in fig. 8: *a*, the road; *b*, open

Fig. 8. Fig. 9. Fig. 10.

channels made at each side, into which the surface-water drains; from which it escapes, by *gully-shoots* placed at intervals, into drains or open water-courses. In improved constructions, a *trap* is placed at these gulley-shoots, as at *c*, the water being led by a small tubular drain to a drain *d*, which conveys it where required.

The road being brought to its proper level, and the *formation surface* well drained, the upper surface is next to be put down—a firm, hard foundation being, by the majority of engineers, considered as essential. This may be obtained by using stones in the way adopted by Telford; or concrete, as used by some engineers, where stone is not so plentiful. The following extract from one of Mr Telford's specifications will shew his method of securing this firm foundation: 'Upon the level bed prepared for the road-materials, a bottom course, or layer of stones, is to be set by hand in form of a close, firm pavement; the stones set in the middle of the road are to be seven inches in depth; at nine feet from the centre, five inches; at twelve from the centre, four inches; and at fifteen feet, three inches. They are to be set on their broadest edges lengthwise across the road, and the breadth of the upper edge is not to exceed four inches in any case. All the irregularities of the upper part of the said pavement are to be broken off by the hammer, and all the interstices to be filled with stone chips, firmly wedged or packed by hand with a light hammer; so that when the whole pavement is finished, there shall be a convexity of four inches in the breadth of fifteen feet from the centre.' Where stone is scarce, a concrete composed of gravel and lime, in the proportion of four parts of the former to one of the latter, and carefully laid down to a depth of six inches, will form a firm foundation. Half of the breadth of the road should only be done at a time; and before the concrete is thoroughly dry, a three-inch layer of hard gravel or broken stone should be placed upon it, so as to incorporate and bind with it; a second three-inch layer is then added. The next point to be attended to is the covering or outer crust which protects this sub-road, and which forms the part on which the traffic is carried on. It is admitted on all hands that the best material for this purpose are angular stones, as introduced by Macadam. These stones should be of such a size as to pass freely through a ring two and a half inches diameter, and are best when made out of granite, whinstone, or basalt, which possess the quality of toughness as well as that of hardness.

In some districts, gravel only is available as an outer covering. In this case, it is necessary to bind it together; which is effected by using loam or sand to fill up the interstices. As before mentioned, in Macadam's plan, no foundation is prepared, but the broken stones are at once laid upon the road; the bottom coating being generally of larger sized, and also of softer stones, where the difference of expense of procuring harder materials is of importance. The covering of this kind of material, technically called *road-metal*, should be spread to a depth of from six to ten inches, as may be found necessary, and raked smooth on the surface.

For some time after a road has been laid with fresh materials, it presents a rough surface, unpleasant enough to travel on; but this roughness is gradually abated; the small stones are crushed into a compact mass; and, finally, the road is smooth, hard, and level. A point of some importance for the early attainment of this result, is to cause the traffic to be spread over the whole surface of the road, and not allowed to run in one or two lines of tracks; while the ruts that are formed in the loose materials are filled in as frequently as possible, until the whole breadth of metalling is brought to one uniform surface. Rain is a great enemy to macadamised roads, and particularly so when accompanied with much traffic. The water softening the material, it is thus more easily abraded by the action of the horses' feet and of the wheels, which soon creates a layer of liquid-mud. If this mud is allowed to lie, it continues to keep the metal below in a soft state, and makes it more easily cut up and damaged. With regard to *fences*, the following is the deliverance of a good authority: 'Fences are necessary along the sides of a road in all enclosed countries; but they should never be allowed to rise higher than four feet on common roads. It is absolutely necessary that the air and sun have free admission to a road; besides, where the fences are high, it gives a sweeping power to the wind, which is not beneficial.'

Paved Roads in Cities.—Where the traffic is heavy, as in the majority of our manufacturing and seaport towns, macadamised roads are soon put out of repair, and are, moreover, dusty in summer and muddy in winter. Paved roads are therefore used, in which the upper covering, as *cc*, fig. 9, consists of oblong blocks of stone resting on a well-prepared firm foundation—a point still more essential in a street than in a country road. A curb-stone, *b*, divides the road from the side-walk or pavement, *aa*, which should slope from the houses to the road, in order that the water may be quickly carried off. In making a paved road, the first step is to remove the soil to a depth of at least a foot, leaving the surface with a slight convexity. Where the soil is soft and clayey, the depth should be greater, in order to receive a layer of fine gravel or sand. On the bed thus prepared, a layer of broken stones should be laid, four inches thick, and consolidated by the passage of vehicles over it before the second and third layers are put on. When the third layer is well consolidated, a layer of gravel is placed to receive the paving-stones, which should be of as uniform dimensions as possible, and the size of which varies according to the traffic. Narrow stones make a better and more durable road than wide ones. The stones are laid in courses from the sides to the centre, and well rammed by a heavy rammer. For first-class work, after each stone is thus rammed down, and a *form* made for it, it is removed, and the side of the stone against which it is to rest covered with good hydraulic mortar; or the stones may be bedded in mortar. In ordinary work, the stones are merely rammed down, and a thin grouting of sand and lime, or melted asphalt, poured over the surface. Where the street is much inclined, the traffic is facilitated by putting down tram-ways of flagstone; and by placing the paving-stones with wide joints, so that a series of grooves are formed, giving a good hold for the horses' feet.

Of late years, a variety of patents have been taken out for forming the outer surfaces of roads of wood-blocks. This kind of pavement was too zealously introduced at first, without mature consideration of the means by which it could be made lasting; and from the failure consequent upon a too hastily adopted practice, the system was as quickly condemned. With a proper foundation, there is no reason to doubt of the success of

wood-pavement in districts where the traffic is not of a peculiarly heavy description. Asphalt pavements have also been tried, but not with much success: they are found to give way rapidly under heavy traffic; and they labour under another disadvantage, in not being easily broken up and replaced when the repair of pipes, &c., is necessary. Recently, cast-iron blocks have been introduced as substitutes for stone, and, according to trustworthy reports, are likely to be useful in many situations.

CANALS.

Many of the preliminary operations of the engineer in carrying out the construction of a canal, are similar in their nature to those required for roads and railways—as the survey of the ground, and the preparation of the working plans and sections. There are, however, certain special features connected with canals which require to be carefully attended to. The most important of these are: First, The nature of the soil through which the canal passes; some soils being so porous as to necessitate considerable outlay to prevent leakage. Secondly, Water can be retained only in a perfectly level channel; and as few districts will admit of this for any great distance, where a break occurs, it is necessary to meet the difference of level by a perpendicular lift, through the medium of a contrivance known as a *lock*. This, as will be explained hereafter, involves the loss of a large amount of water, to meet which, and to provide for waste by evaporation and percolation, the canal requires a *feeder*, a species of auxiliary canal, which conducts supplies of water to the *summit level*, or highest point in the route. The water is there admitted into the canal as required, or is stored up in a reservoir to serve as a reserve supply in time of drought.

The section or form of the canal varies according to circumstances—usually it is in the form shewn in fig. 10: *abcd*, the water-way; the towing-path is shewn at *e*; the side-drain at *f*; and *g* represents the face of cutting through which it is supposed to pass. The width of the water-way at bottom should be equal to twice the width of the boats; the width at top, such as to allow of two boats passing with ease. The slope in some works is not carried up to the level of the towing-path, but a horizontal bench is left about a foot above the water level; this is sometimes planted with aquatic plants, or paved with stones, to protect and strengthen the sides. In certain soils, to prevent filtration the bottom and sides are lined with a puddling of clay. This prevention of filtration, in cases where the canal is carried along an embankment, is of the utmost importance, as, if allowed to go on, it may speedily destroy the whole embankment. Fine sand sprinkled on the water is found to sink and stop up crevices pretty effectually. In some strata it is, however, necessary to line the canal with masonry.

Locks are rectangular chambers, of width and length sufficient to admit a boat easily; the depth of a lock is regulated by the amount of fall, or difference between the level of the upper canal, *aa*, and lower, *bb*, fig. 11.

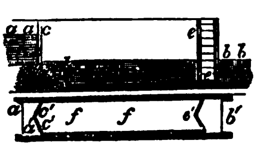


Fig. 11.

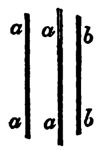


Fig. 12.

The walls of the lock are usually made with a slight batter or slope, and terminated near the upper gate, *cc*, by a vertical wall, *d*; this projects above the level of the bottom of the upper canal a few inches, and presents an angular surface, termed the *mitre sill*, against which the gates close. The gates, when closed, form an angle, as *c'c'* in the plan; in this way they mutually support each other, and the pressure of the water tends to keep them all the more firmly closed. In constructing the retaining-walls of locks, two things have to be guarded against—the pressure of the earth outside tending to force them in, and that of the water inside, acting in the opposite direction. The floor is usually concave. The recess made in the *head-bay*—as the upper part of the lock is termed—is called the *gate-chamber*, as *c'c'*, to admit of the gate falling in it, so as to keep the water-way quite clear when the gates are open. The gate turns on centres or pivots in the corner of the recess, which is termed the *hollow quoin;* and is curved, to admit the heel or quoin post of the gate to move freely, and at the same time allow no leakage. Two methods are in use for emptying and filling the lock-chamber: (1) by means of sluices in the gates themselves; (2) by drains or culverts leading from the upper canal to the lock-chamber, and from this to the lower canal—the flow of water through the culverts being regulated by valves. Each plan has its advocates; the first is more easily repaired. The lock-gates are closed either by windlasses, or, as is more usually the case, by balance-beams, which are connected with the mitre and quoin posts, and project considerably over the side of the chamber; these projecting beams are used as levers by men who press against them, and thus open the gates. Where a canal enters a river, great attention must be paid to the construction of the lock, which is here termed a *tide* or *guard lock*, and is provided with double gates, so that boats can pass either way according to the level of the river, whether it be above or below that of the canal. The following is the mode of operation of the ordinary lock we have above described, and illustrated in fig. 11. Suppose a boat is to pass from the lower to the upper level, the gates, *e*, *e*, are opened, and the boat is passed into the chamber *ff*; the gates, *e*, *e*, are then closed, as at *e'* in the plan. The sluices in the upper gates, or the valves in the upper culverts, are then opened; and the water rushing into the chamber *ff*, gradually fills it, till the level is equal to that of the upper canal, *aa*; the upper gate, *cc*, is then opened, and the boat is floated into the upper canal. If another boat is now to be passed from the higher to the lower level, it is at once floated into the chamber *ff*. The upper gates, and the sluices, or culverts, are then closed, while the sluices of the lower gate, or the lower culverts, are opened, and the water flows into the lower canal, till the lock-chamber is emptied, down to the level of the lower canal. The lower gates, *e*, *e*, are then opened, and the boat is floated to the lower canal. Here it is evident that a quantity of water is passed from the higher to the lower level, and a certain waste involved. To prevent this, a variety of means have been proposed and adopted; some of them to economise the loss, others to supersede the use of locks entirely, by certain arrangements of mechanism. In America, inclined planes are used, in which rails are laid down, and the boat, placed in a *cradle*, is pulled up, and delivered to the higher level. A somewhat similar plan has been adopted on the Monkland Canal in Scotland—not with a view, however, altogether to supersede the locks, but to save time and water by passing the empty boats from a low to a high level, the traffic in this canal being all downwards. The *caisson* containing the boat is hauled up by the power of two high-pressure engines at the top of the incline. Another plan, in use at the Grand Western Canal, may be noticed here. The principal feature is the employment of two tanks or caissons capable of receiving a boat, and suspended in such a way by chains passing over pulleys as to balance each other when both are full of water. When a boat is required to pass—say from the high to the low level—one of the tanks is brought up to the level of the upper canal; and by peculiarly ingenious mechanism the boat is passed into

it, *a portion of water equal to the weight of the boat* (see HYDROSTATICS) at the same time passing out of it. The two tanks—one containing water only, the other a boat with a portion of water—still, therefore, balance each other. To make an excess in the weight of the upper, a portion of water is allowed to pass out of the lower tank: the machinery being released, the upper tank with the boat descends, and the lower one ascends. The tank is, by the same means as above alluded to, connected with the lower canal, into which the boat then floats. This plan, the invention of Mr James Green, effects a large saving of water and time, a boat being lowered in three minutes a fall of 46 feet, which would take six locks and half an hour of time. For full working details, see Mr Law's work on *Civil Engineering*. In some cases, the method adopted for saving water during lockage is a pond placed alongside the lock, communicating with it by a culvert provided with a sluice. When the lock is full, and the boat to be lowered to the low level, instead of opening the sluice in the low gates, allowing the water to run into the lower canal, the sluice connecting the lock with the pond is opened, and the water runs into the latter until the level in the lock and pond is equal. This sluice is then closed, and the remainder is allowed to run into the lower canal in the usual way. On a boat being lifted from the low to the high level, the low gates are closed, and the pond-sluice opened, when the water rushes into the lock-chamber till the level in both is equal; the remainder of the water is supplied, as usual, from the upper canal, the pond-sluice being closed, and the high-gate sluices being opened. By this arrangement, about one-third of the water is saved. By having two ponds, one on each side of the lock-chamber, and of unequal depths, into which the water is admitted alternately, one-half may be saved.

Where the fall is great, a chain of locks is used, forming a kind of water-stair; the upper gates of the lowest forming the lower gates of the next highest lock, and so on. Where a valley is to be crossed, instead of using a series of locks to descend, and another series to ascend, the canal is formed on a series of arches, which is termed an aqueduct. The most celebrated structure of this kind is that designed by Mr Telford, for carrying the Ellesmere and Chester Canal across the valley of the Dee. It is upwards of 1000 feet long—the highest portion being 127 feet above the level of the river. The principles upon which aqueducts are constructed, are similar to those already described under the head of Bridges in the present article.

RAILWAYS.

In the number on INLAND CONVEYANCE, will be found notes on the historical, commercial, and social considerations connected with railways; it is our duty here to enter briefly into the subject of their construction, a matter which belongs exclusively to the profession of the civil engineer. This we propose to notice under the following heads: 1*st*, The laying out of the line, with the methods adopted to save material and to secure its economical working. 2*d*, Cuttings and Embankments. 3*d*, The boring of tunnels. 4*th*, The raising of bridges and viaducts. 5*th*, The permanent way.

1. *The Laying out of the Line.*—The correct theory of a railway is, that it shall be level from end to end, and that it shall be in a direct line. Accordingly, in the earlier constructions, vast sums were expended to have level lines, avoiding as much as possible all inclines or *gradients*, as they are technically termed. Such, however, have been the vast improvements effected, of late years, in locomotive mechanism, that considerable modifications in this department of railway construction have been introduced; so that gradients of a class which formerly would have been set down as impracticable, are now in almost general use. Indeed, in opposition to those engineers who hold that lines should be as level as possible, on the ground that they will be most economically worked, many now contend that the system of making lines with alternating steep and easy gradients, within certain limits, is more economical in working, inasmuch as the vast outlay in making cuttings and embankments is in a great measure avoided, and the capital thus saved more than compensates for the extra cost of locomotive power, while the speed lost in ascending may be gained in descending. The lines constructed on this principle are favourable in their results to its general adoption. In cases where the situation of one terminus is at a considerable elevation above that of the other, it is a matter of dispute whether the best plan, where the nature of the country admits of both, is to spread the inclination over a great distance, or to concentrate it in a few steep gradients, which may be overcome either by stationary engines or additional locomotives. In view of the fact that, in general cases, the load drawn by locomotives must be regulated by the steepest gradient they have to overcome, eminent engineers are now beginning to advocate the latter plan of having a few steep gradients with extra assistance at these points, the remainder and easier part of the line being traversed by the locomotive unaided.

As gradients are deviations from the theoretical level of a railway, necessitated by the exigencies of the country through which it passes, so curves are deviations from the straight line, which forms the other theoretical requirement. All deviations from the direct line must be in easy curves, abrupt bendings not being admissible, from the circumstance that the axles of the carriages are always parallel. This necessarily limits the curve which may be necessary to change the direction, as every bend of the tracks must evidently cause some lateral rubbing or pressure of the wheels upon the rails, which will occasion an increased friction. As the wheels are fixed to the axles, so that both must revolve together, the wheel that moves on the outside of the curve or longest rail would slide over whatever distance it exceeds the length of the other rail, but for a peculiarity in the formation of the wheels, which are keyed upon the axle, so as to have a slight play between the rails, and are formed of a conical shape, the larger diameter being close to the flanges, so that when the flange of one wheel is pressing against the outer rail, the other wheel on the same axle is running on that portion of it where the diameter is smaller, and thus a greater space is traversed by the wheel on the longest rail, and the pressure against it diminished. Still further to counteract the tendency of the carriages to press against the outer rail of a curve, or even to fly at a tangent off the rails altogether, the outer rail is elevated in proportion to the rapidity of the bend.

Formerly, curves of less than a mile in radius were considered dangerous; experience, however, has shewn that they may be made much less. Dr Lardner found that even with a radius of half a mile, there was no appreciable augmentation of the resistance at any speed attained. Curves of 220 yards radius have been traversed for years with safety, at the usual speed.

In laying out a railway, another point attended to is the economisation of the material; to effect this, the amount of cutting and embankment should be as equal as possible, and each cutting have a corresponding embankment near it, to which the removed earth may be taken at as little cost as possible; thus avoiding the necessity for raising banks of waste earth from the cuttings on the one hand, or for buying land to excavate for raising embankments on the other. The width to be given to the surface of the road depends, to some extent, on the width of gauge adopted. The principal gauges used in Britain are what are known as the 'broad' and the 'narrow.' The broad gauge is that adopted on the Great Western, having the distance between the rails 7 feet; the narrow gauge is 4 feet 8½ inches, and is that which is followed by the generality of

railways in the island. Throughout Ireland there is a uniform gauge of 6 feet 2 inches. It is an unfortunate circumstance that uniformity of gauge was not established in Britain; the want of it gives rise to great inconvenience in carrying on the 'through' traffic. In fig. 12, which shews at the same time the relative proportions between the broad and narrow gauge, we give an illustration of one of those expedients by which the carriages of the narrow-gauge line can be made available on the broad, and *vice versâ*: *aa* shews the narrow-gauge line, *bb* the extra line of rails. This is the plan adopted to join the Great Western line with the previously laid narrow-gauge line from Gloucester to Cheltenham. A very ingenious arrangement is made at the point of junction, by which the broad and narrow gauge carriages take their respective rails without requiring any attendance. It is difficult to state which of the two gauges is the best; each has its strenuous advocates; and the question has been discussed, both in parliament and at scientific meetings, with more warmth than the dignity of the eminent men engaged in the dispute seemed to warrant. Although in point of steadiness of motion and of safety at high speed, the broad gauge has advantages over the narrow, it would seem that the latter is, on the whole, best calculated for the business of the country, and the extension of the benefits of railway communication to agricultural districts. In point of cheap construction, the advantages are all on the side of the narrow gauge; the extra cost involved by the broad may be set down at from a fifth to a seventh of the cost of the narrow.

An important duty of the civil engineer is the preparation of the plans and sections, which require to be laid before parliament when application is made for authority to construct the railway. To aid him in this, the engineer procures an Ordnance or other map of the district through which the railway is to run, on which he marks the direction of the line, and ascertains the best method of laying down the base-lines for the survey from which the plan is made. The operation of taking the levels is then gone through, and the section prepared from the observations. In the parliamentary plans, the direction the line takes is accurately laid down, but a limit of deviation equal to 100 yards on each side of the line is allowed, and five feet in the section; in town districts, however, the limits of deviation are less—thirty feet, and two feet section. In fig. 13, we give a sketch of a plan of a line, in which *ab* is

Fig. 13.

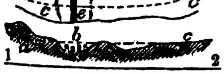


Fig. 14.

Fig. 15.

the line of railway passing through a country district; *cc*, *dd*, limits of deviation; *ee* shews it crossing a river. In fig. 14, we give the section, 1, 2, being what is called the *datum line*, from which the heights to the surface are measured. At *a*, the line is shewn passing a hill or elevated part, at which point a cutting or tunnel will be made; at *b*, a valley is crossed by a viaduct; and at *c* is an incline. Wherever the line crosses a road, a cross-section is made of this portion, in order that the engineer may be able to judge of the best method of laying out the approaches. When the actual construction of the line commences, the working-plan is the first operation to be attended to; in this, all the measurements, &c., are again taken, with greater accuracy than in the parliamentary plans. When the plan is completed, the exact line of the railway, within the limits prescribed by the Act, is determined upon, and marked out on the ground by stakes driven in at regular intervals of 66 or 100 feet, which are numbered for easy reference.

The centre line of the railway being thus ascertained, the working-section is then proceeded with, care being taken to observe every change in the undulations of the surface, and also the height at the stakes previously driven in, which are shewn on the section, and the observed levels marked thereon: when required by the nature of the ground, *cross-sections* are also taken.

The gradients are next decided on, care being taken so to adjust these that the cutting and embankment be as nearly as possible balanced, and the most judicious crossing of all roads and streams effected. The height of the embankments and depth of cuttings being now fixed, the engineer is in a position to set out the surface width, which varies according to the nature of the ground. Great judgment is required in laying down the line, in order to save extra bridges, cuttings, &c., which an injudicious curve might necessitate. In marking out the direction and levels of a tunnel, great care is requisite; the slightest inaccuracy will often involve a large additional expense, from the points of the gradients and direction not meeting with exactitude. In setting out the direction of the tunnel, a pole is fixed on the summit of the elevation through which the tunnel passes, from which the termini may be observed; other poles are put between these and the centre pole; and in the line of direction thus obtained, the shafts are sunk at the necessary distances, the depth of these being obtained from the section. Where a curve is employed for the line of the tunnel, it must be carefully set out on the surface of the ground. When the shafts are sunk, the direction in which the head-way is to be cut from the bottom of these, is ascertained by employing a compass, the direction being the same as that shewn by the indicated line on the surface of the ground.

In addition to the general plans and section here indicated, the engineer has other important drawings and documents to prepare; as designs for special constructions—bridges, viaducts, framing, tunnels, &c., the peculiarities of which may require the exercise of a high degree of engineering skill. Estimates also of the quantity of land required are to be prepared, and calculations made of the quantity of earth contained in the formation of embankments, and that taken from cuttings and tunnels. The majority of these operations are more or less facilitated by various publications, as Earth-work Tables, &c. Having thus glanced at the various points involved in the laying out of the line, we are now prepared to enter into the consideration of those connected with what may be termed the strictly constructive departments—the first of these forming the second division of our subject.

2. *Cuttings and Embankments.*—In carrying on cuttings, a considerable amount of forethought and care is necessary. Much depends upon the nature of the strata to be cut through. If the soil is loose, and much penetrated by springs, the expense of the undertaking is greatly increased. The slope of the sides depends upon the material. Rock is cut almost perpendicular; chalk generally admits of a small slope being used; while loose earth, or a stratification of clay and sand alternately, require to be finished with a much flatter slope, so that the sides may not slip in. In commencing a cutting, the coating of soil is first removed, and a gullet or channel cut, to admit of a set of temporary rails, on which the wagons containing the excavated material are run out to the embankment where it is to be deposited. As the cutting proceeds, the width is increased, to admit of the rails being laid along each side, thus allowing two sets of wagons to be filled at the same time. If the cutting is of large dimensions, *runs*, or sets of planks, are placed on the sides in different directions, along which the soil taken from various elevations is conveyed to the wagons. To prevent the water

accumulating—one of the greatest inconveniences attendant upon the operation—the cutting is commenced at the lower end, so that the water can be easily drained off and allowed to run away. As before stated, it is desirable to have a cutting in near proximity to the place where an embankment is required, and if it can be arranged to have the inclination from the cutting to the embankment, so that the wagons can run down by their own gravity, regulated by a break, a considerable saving in the expense of execution is effected. Wagons are constructed so as to deposit the earth either from their sides or ends. The latter are so formed—being freely supported on two rollers—that, on gaining the end of the embankment, their progress being suddenly checked, the inertia causes the body of the wagon to tilt up, and to shoot the earth over the end of the embankment, which is in this way gradually lengthened. The body of the wagon is prevented from leaving the frame by two catches, which take hold of the rollers. The embankments are run out the full breadth at once, the rails at the *tip* being spread out fan shape, so that wagons can be directed either to the sides or centre as may be required. The embankments are also in the first instance formed to a higher level than the permanent one, to admit of subsidence before the rails are finally adjusted. The finishing of cuttings is a matter of great importance. The slopes are generally covered with earth, and grass is allowed to grow, which binds the soil together, and prevents it being carried off by surface-water. They are in some cases faced with retaining-walls, which effects a considerable saving, and affords great facilities for draining. In some situations it is also necessary to form small drains of tiles or broken stones obliquely across the slopes of the cutting, and other drains are cut to intercept water flowing in from higher levels; effective drainage being a most important item in construction. To the want or inefficiency of draining, the failure of earthworks is found generally attributable.

In cuttings, the great point to be attended to is the avoidance of *slips*. After every care has been taken, and the railway fully completed, the sides have frequently fallen in, and stopped for a time the traffic of the line. As before stated, the amount of slope or inclination of the sides depends upon the material, each material having a tendency to remain at rest at a certain angle, which is termed the angle of repose. Generally, for every vertical foot of depth of cutting, a foot and a half of slope is allowed. In fig. 15, we give the sketch of a railway cutting: *a*, *a*, the lines of rail; *b*, the drain between; *c*, *c*, the side-drains; *d*, the sloping sides. In some cases it is necessary, to insure stability of the cutting, to build retaining-walls, as *c'*: the drainage-water from the side drains is led to the central drain, *b*, by small branch-drains. In many cases the central drain is dispensed with, and only side and branch drains formed.

The most remarkable application of science and engineering in dislodging a mass of material without the necessity of cutting, was the removal of a huge chalk-cliff on the line of the Dover Railway by blasting, the ignition of the powder being effected by means of galvanic batteries. A mass of material, which would have cost £10,000, and occupied twelve months in cutting, was thrown down in a few seconds at a cost of £7000.

Some idea of the magnitude of railway operations may be formed when we state the fact, that if the material excavated in the making of the London and Birmingham Railway was made into a bank a foot broad and a foot deep, it would go three times round the earth at the equator.

The slope of embankments is usually made equal to that of the cuttings, it being considered a rule of pretty general application, that the angle at which the cutting stands will suit for that of an embankment, constructed of the earth taken from the former. On completion of the embankment, the slopes are covered with soil, and sown with grass or clover seeds, the vegetation of which ultimately forms a turf, which tends greatly to keep the surface of the embankment in good repair. In some cases, the nature of the ground over which the embankment has to be carried renders its execution a matter of extreme difficulty; and the skill of the engineer is taxed to the utmost. The most important work of this kind ever executed was the Chat Moss embankment on the Manchester and Liverpool line, Mr Stephenson being the engineer. Other morasses—as the Stratford marshes, the Ashton and the Cockwood—have also called forth great skill on the part of the engineer. In the first mentioned of these cases, the ground was of so yielding a nature as not to allow even cattle to walk over it. The first operation was to thoroughly drain the moss, and thereafter to form the embankment by the light dried moss itself. At another portion, where the ground was of such a yielding nature that it absorbed an immense mass of material without result, Mr Stephenson adopted the plan of laying hurdles of wicker-work on the absorbed layer of dried moss; upon these hurdles, the gravel was placed to form the permanent way, wooden sleepers being employed to support the rails.

3. *Tunnels.*—It is considered a rule in railway engineering, that if a cutting is to be more than sixty feet deep, and no embankment is near to which the earth may be taken, it is cheaper to bore a tunnel than make the cutting.

The shape of the tunnel depends much upon the material through which it has to be formed; for a mobile soil, it is nearly a circle. In fig. 16, we give a

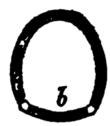


Fig. 16.

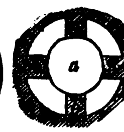


Fig. 17.

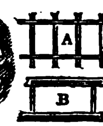


Fig. 18.

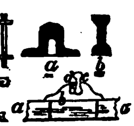


Fig. 19.

sketch of the usual form of a brick-lined tunnel; this is of an oval shape, the sides and top being described with arcs of circles, and the bottom an inverted arch. The usual width is about twenty-four feet, the height, from the crown of the arch to the level of the permanent way, from twenty-four to thirty feet. In order to ascertain the nature of the strata through which the tunnel has to pass—and from this to decide on the form of its section, the thickness of the retaining masonry, and to provide for such casualties as may happen in the construction of the work—trial borings are made, or shafts are sunk, which are afterwards used for the working-shafts. These shafts are generally at equal distances; and, within certain limits, the nearer they are, the quicker and cheaper is the tunnel constructed—the labour in excavating and removing the material increasing as the distance increases from the point of labour to the foot of the shaft. As shafts are, however, expensive, they may be too numerous, and their cost exceed the saving effected as above noted. The shafts are sunk to the depth of the crown of the intended arch as follows:—Where the strata are uniform, and not likely to be much intersected by springs of water, a circular excavation is made as deep as the strata will allow, and at the bottom of this, a *curb* or circular ring of timber is placed. The internal circle of the ring is equal to the diameter of the shaft, and its breadth a little greater than the thickness of the brick or stone lining to the shaft. On this curb the lining is constructed, and the earth well rammed in behind as the work progresses: this is an essential point. When the top section has been thus finished, the excavation of another section is proceeded with; which, however, requires care to prevent the unequal sinking of the

lining already built. The centre portion is at first excavated to the necessary depth, leaving a ring of earth to support the wall, as in fig. 17, where *a* is the central opening, *bb* the wall. Four recesses are cut, as at *bb*, into which *shores* or timber props are inserted, and carefully fastened to the under side of the curb, and to sole-plates at their feet, so as to support the curb and the wall resting on it. The excavation is then made to the full diameter, and a second curb laid down, on which the building is carried up to meet the curb above. On this being done, the props are removed, and the recesses which they occupy built up. The same process is repeated till the necessary depth is obtained. This is the simplest method of sinking shafts; in cases of unusual difficulty, other plans have to be adopted; frequently such treacherous material is to be passed through, that entirely new appliances are to be designed, but our space does not allow us to enter further into the subject. We proceed, therefore, to trace out the succeeding operations. As the excavation is proceeded with from the crown of the arch to a short distance below the bottom of the intended tunnel, the sides are carefully lined with timber, and every means taken to prevent all disturbance of the soil. The requisite shafts having been thus constructed, a *drift-way* is commenced, to join the two contiguous shafts. This is usually some five or six feet wide, and seven or eight high, and serves the purpose of draining the work—opening up the means of communication between the shafts—and allows the sides of the tunnel to be set off with greater accuracy. The drainage from the drift-way is collected at the bottom of the shafts, when it is necessary to pump it up to the surface. The drift-way being completed, the excavation for the full width of the tunnel is commenced on each side of the shaft, the earth removed being taken up to the surface through the working-shafts. As the excavation is made, the sides and top are carefully supported by timber *centering* and planks. The building should be commenced when about twenty feet are excavated, under ordinary circumstances; and as the sides of the arch are carried up, the timber lining at the back which supports the earth must be gradually removed, and any vacuity or space left behind well rammed up. The crown of the arch is turned on a centre similar to that used for bridges. On the excavations from adjoining shafts approaching each other, the greatest care is requisite to prevent the improper disturbance of the earth between their ends. When the tunnel has been finished on each side of a shaft, the timber lining should be removed, the ground excavated, the brickwork of the tunnel built and carefully bonded with that of the portion previously completed. For the purpose of admitting light, and freeing the tunnel from smoke, steam, &c., some of the shafts may be left open, which in this case are made of larger dimensions than simple working-shafts. The ends or *fronts* of the tunnel are faced with a retaining-wall, and frequently finished in an ornamental manner. The thickness of the brickwork of the arch is usually eighteen inches. Great care is requisite to prevent the accumulation of water behind the brickwork; a drain is generally laid along the centre of the invert *b*, fig. 16, to which other drains from the sides are led.

Tunnels passing through solid rock or chalk are left as excavated; but the strata through which some pass are so diversified, that brick-lining is frequently necessary. In no department of railway construction do difficulties so frequently arise as in tunnel-making; these call forth the utmost powers of the engineer, and seem at times destined to baffle his ingenuity and resources. Of remarkable tunnels may be mentioned the Box Tunnel, on the Great Western Railway; it is 9400 feet long, and 400 feet below the highest part of the hill through which it goes: thirteen shafts were required in its ventilation and construction. The longest tunnel in England is the Summit Tunnel, on the Sheffield and Manchester line, which is more than three miles long; it took six years to finish; the average depth of the shafts was 600 feet; nearly 160 tons of gunpowder were used in blasting, and 8,000,000 tons of water were pumped from it. The cost of constructing tunnels varies from £20 per yard in the easiest, to £100, and £150 or £160 for the most difficult strata.

4. *Bridges and Viaducts.*—Railway bridges of one arch are generally used to carry the railway over roads, canals, and short ravines; valleys and rivers are generally crossed by bridges containing a number of arches, which are termed viaducts. Where the bridge crosses a road, &c., at right angles, its construction is a matter of ease; where, however, the road, &c., to be crossed is oblique to the line of railway, a skew-bridge is used, in which the arch is oblique to the abutments. Natural and local difficulties have frequently necessitated the erection of bridges of a peculiar form, as the 'telescopic' drawbridge over the Avon, where the railway is placed upon a movable platform, which is made to pass over, or leave the water-way clear, as desired. But the most remarkable construction yet carried out is the Britannia Bridge, which crosses the Menai Strait. This, the most wonderful engineering project connected with railways, has been so frequently described, and its proper elucidation would take up so much space, that we have merely to state that it consists of two long tubes, one for the up, the other for the down lines, each tube forming a rectangular tunnel or square box of malleable iron, the sides, top, and bottom of which are composed of a series of cells. These tubes are supported on piers, one of which rises from a rock in the centre of the stream, to a height of 230 feet. The total length of each tube is 1492 feet, and they cost in their construction half a million.

Some of our railway viaducts are gigantic undertakings. The one over the Valley of the Dee, on the Shrewsbury and Chester line, is 150 feet above the level of the river, and is nearly the third of a mile in length. While stone or brick was almost invariably used in earlier constructions, timber alone, or timber combined with stone, or brick, is now adopted with success. A timber viaduct connects the Bricklayers' Arms station with the main line of the Brighton Railway. In Scotland, timber-trussed viaducts of great span have been introduced with economical results. The timber is preserved from the ravages of insects and from dry-rot by a chemical process. Of viaducts extending into, or crossing arms of the sea, a remarkable instance is afforded at Hull; it extends 1500 yards into the estuary. Some railways are almost wholly constructed on arches, as the Blackwall and Greenwich lines. The spaces below the arches are let out as warehouses, &c., and thus yield a revenue. A remarkable species of viaduct or bridge is met with at Newcastle-on-Tyne. Both railway and roadway are carried over the river by one structure, the latter being suspended from the great arches which carry the railway; the length of the carriage-road is 1330 feet, its height above the river is 80; the height of the railway is 102 feet.

5. *The Permanent Way.*—When the proper level has been attained throughout, the road is prepared to receive the rails by being *ballasted*, which consists in laying a stratum of broken stone, gravel, or chalk to the depth of fifteen to twenty-four inches. The rails are connected together by *chairs*, which formerly used to be fixed in square blocks of stones. Stone-blocks have been since discarded, and wood-sleepers are now almost universally adopted. There are two methods of laying wood-sleepers: one in which the timber supporting the rails is laid down in a continuous line, and connected together at intervals; the other, in which a series of timbers are laid transversely at certain distances from each other. The longitudinal bearing is that which has been chiefly used on the broad-gauge lines; the

rails being at once fastened on the timber, without the intervention of chairs. It is stated that the *bite* of the locomotive on the rails so laid is not so great as on the cross-sleepers. The latter plan is that which is chiefly adopted. The distance between the sleepers varies, according to the weight of the rails, from two and a half to four and a half feet. They are now made of larger size than formerly, and subjected to an antiseptic process before being laid down. In fig. 18, B shews the method of laying the longitudinal bearings, and A the cross-sleepers. In the longitudinal bearing, the form of rail is that known as the bridge-rail, as at *a*, fig. 19, which is fastened to the sleeper by nails or bolts passing through holes made in its lower flanges. Where cross-sleepers are used, the rails are supported by chairs; the sections of rails of this class are numerous. In fig. 19, *b* shews one in use on many railways; it is known as the 'double-T' rail. In fig. 19, at *c*, is a form of chair much used. The body of the chair, *b*, is of cast iron, and is fastened down to the sleepers, *a*, *a*, by wooden trenails, or iron spikes, passing through holes made in the sole of the chair. One side of the space into which the rail, *c*, is passed is curved, against which the rail rests, the other side, *d*, is flat; and into this space the compressed wedge or key, *d*, is firmly driven. These keys are generally of hard wood, previously steamed, and compressed in a hydraulic press. This treatment prevents them from shrinking in dry weather, and becoming loose.

In laying the rails, the exact width is accurately adjusted by using a gauge; and space is left between the ends of the rails to allow of their expansion. Drainage should also be attended to; for this purpose, open drains are generally cut across the ballasting at right angles to the line of rails.

The form of the rail has been a matter which has always claimed the attention of the engineer, and a variety of shapes and methods of manufacture have been introduced. Mr Peter Barlow's 'cast-iron chair and sleeper' system has been adopted with great success in two lines of railways. By it, he obtains a hard and rigid line, which he holds to be desirable. Mr Barlow's brother, W. H. Barlow, has introduced another method of permanent way, which he terms the 'broad-flanged wrought-iron rails.' This is coming largely into use, and seems likely to bring about a revolution in this department of railway engineering. As the capabilities of the railway system have been developed, the rails have been gradually increased in weight. At first, they were laid down of a weight of 35 pounds to the yard; this gradually increased to 50, 62, 72, till a weight of 85 pounds to the yard is now sometimes used.

As to the important point of the durability of the rails, it was stated in a report on the subject to the directors of the London and North-western Railway, that the average 'lifetime' of the rails was twenty years, after the expiry of which term the whole line would be required to be relaid. It has been calculated that one engine abrades no less than 2·2 pounds from the rails by passing over sixty miles, and each ton of load about an ounce and a half. The cost of a mile of permanent way may be set down at £2000 to £2400.

To meet the various exigencies of railway traffic, provision must be made to enable trains to be taken from one line of rails to another, or from the main line to *sidings*, or *vice versâ*. This is effected by *switches* and *turn-tables*. Where a switch is used, the rails of the siding are brought up to the main line; the ends of one rail of the latter and one of the former are made movable—these are called the *tongues* of the switch—and are brought to a narrow point, so that the wheels may pass without any shock from one line to the other. The points are kept in their proper position by a weight which is attached to the lever, this being moved as desired by the pointsman. On some railways, self-acting switches are used; these allow the carriages to pass from the main line to a siding, but not to return without the intervention of the pointsman. This prevents accidents from carriages being moved, by the wind or other causes, into the main line from a siding. In fig. 20, we give a diagram illustrative of the arrange-

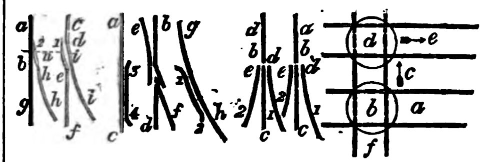


Fig. 20. Fig. 21. Fig. 22. Fig. 23.

ment of a siding, shewing the action of the switch. Let *abg* be the left-hand main-line rail, and *cd* the right-hand one; this is continued at *ef*. At this point, a portion of a rail, *e*1, is jointed, and is gradually tapered nearly to a point, this fitting into a notch made in the main rail *cd*. The right-hand rail of the siding is at *ii*; the left hand at *hh*. At the point *h*, corresponding to *e*, a tapered tongue, *h*2, is jointed, fitting into a notch in the rail *abg*. The two tongues of the switch are connected by a bar, *n*, which is moved by a handle at *b*. In the position in the diagram, the flange of the right-hand wheel will enter the space left between the end of the tongue, *e*1, and the rail *cd*, and will consequently leave the rail 1*ef*, and follow *cdii*; the other wheel will go on the rail *hh*, and the train will thus pass into the siding. The tongues of the switch are ordinarily kept in the position the reverse of this, by means of a weight attached to the end of the lever, as explained above. In order to prevent the flanges of the wheels striking against the point 5, where the main line and siding intersect, two guard-rails, 1 2, 3 4, are placed, as shewn in fig. 21, *ac*, *bd* being the main line, and *ef*, *gh* the siding-rails. In fig. 22, we give a sketch of another arrangement of switch: *a*, *d*, the main rails, with the tongues of the switch, *bb*; *ec* the continuation of the main line. When the switches *b*, *b* are in the position in the diagram, the train proceeds along the main line; by moving them till they coincide with *dd*, the train proceeds along the right-hand siding *d*1, *d*1; if moved to *ee*, the train proceeds along *e*2, *e*2. Where single carriages are to be moved from one line to another, a turn-table may be used. This is a circular platform, revolving on wheels or rollers beneath. It is provided with a set of rails, on which the carriage is placed; the table is then turned round, to make the rails correspond with those of another line as required. Thus, if a carriage is required to be taken from the line *ab* to the line *de*, fig. 23, it is passed on to the turn-table *f*, which is then wheeled round until the carriage is in the position shewn by the arrow at *c*. It is then moved along the cross-rail *bd*, to the turn-table *d*, where it is again wheeled till it assumes the position of the arrow *e*, where it can be moved along the line of rail *de*. Carriages can also by this contrivance be removed from any line, as *a* or *d*, to a cross-line, as *c*.

As these turn-tables are fixtures, a plan of moving carriages from one line to another, and capable of being used at various points, is required. This is known as a *traversing-table*, and is a low rectangular platform, on to which the carriage is moved, and thence transported to any point as desired, the whole being effected by simple mechanism. It is particularly useful at stations.

In thinly populated or agricultural districts, single-lined railways are likely to come into general use. On single lines, trains are allowed to pass each other by means of sidings, where there are two lines of rails connected with the main line by switches which are made self-acting, and are so adjusted that one train passes over the right, while the train approaching in the opposite direction takes the left set of rails.

In addition to the subjects above considered, it is

the duty of the railway engineer to devise the various arrangements necessary to work the line—as signal-stations, tanks, and apparatus to supply water and fuel to the engine, roofs of stations, &c.; for which we must refer the reader to works treating of railways more in detail. The management of railways, and their commercial and social aspects, are noticed in the paper on INLAND CONVEYANCE.

MARINE ENGINEERING.

This division of our subject comprises the construction of roadsteads, breakwaters, harbours, docks, and the protection of sea-coasts.

Roadsteads are of two classes—*land-locked*, and *open*. In the former, the anchorage is protected from the weather and the action of the deep-sea waves by projections of the land; in the latter, the anchorage is more or less unsafe, by being fully exposed to the ocean-swell and the winds, and consequently requires special construction, in order to lessen the danger. This is usually effected by laying down a breakwater, which may be defined as an artificial island, constructed by throwing huge blocks of stone into the sea, and allowing them to assume the position produced by the action of the waves. The waves, rolling in from the ocean, expend their force on this structure, so that the water in the inner side is comparatively still. The interior of the breakwater is filled in with smaller stones, the facing being made of the heaviest blocks, laid with as much care as is possible under the circumstances. Experience, however, has shewn that where the exposure is great, this rough facing should not be trusted to, but that a covering of heavy blocks, carefully adjusted to one another and set in hydraulic cement, is requisite to resist the action of the waves under the heaviest gales.

The most gigantic of all the works of this kind, and the first in priority of execution, is the breakwater at Cherbourg, in France, of which a section is given in fig. 24. This work is of extraordinary dimensions—in length, it is nearly 4120 yards. Up to the level of twenty feet below low-water mark, the breakwater is composed of small stones, and it is ascertained

Fig. 24.

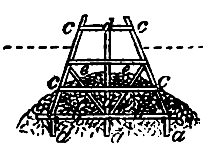


Fig. 25.

that the action of the waves up to this level is comparatively slight, inasmuch as the original outline of the mass has not been materially disturbed. Above this level, however, the waves exercise an enormous force, displacing, in heavy gales, blocks of the largest size, and gradually altering the outline presented to the sea, making it more and more flat every year. In 1829, it was considered necessary to crown the breakwater with a vertical wall. The top-surface was covered with large loose blocks, and the wall rests upon large blocks of *beton*, or artificial stone. The wall is constructed of heavy courses of granite ashlar, the interior being filled up with rubble. Another celebrated example of this kind of structure is the Plymouth breakwater, designed to shelter the sound which forms the entrance to the harbour of Plymouth and Devonport. The length of this is 1700 yards, the central part being 1000 yards, and the two arms, which make an angle of 135° with the centre, being 350 yards each. The width at the bottom is 133 yards, and at top 15. Part of the sea-face is paved with large stones set in hydraulic cement, from the top to the level of low-water at spring-tides. A light-house, 60 feet in height, is formed at one extremity. Experience has proved that the vertical wall in the Cherbourg breakwater is more effectual in maintaining still water at the land-side than the slope of the breakwater at Plymouth, although the former is much more liable to damage than the latter

What are termed *floating breakwaters* have been proposed at different times, but as yet, we know of no instance of their adoption on a large scale. The late Sir S. Bentham drew out a plan of such a breakwater for Plymouth, the distinguishing feature of which was the construction of prismatic floats of timber, securely moored across the entrance to the Sound. The floating breakwater of Captain Taylor consists of timber caissons or frameworks, fastened together by chains of a peculiar construction; and is recommended by the inventor on grounds of economy, quickness of erection, and, from its open character, preventing the deposition of silt, which a solid erection is likely to promote.

Harbours may be classed as natural, artificial, and composite—that is, partly formed by nature and partly by art. Any creek, sound, or estuary sufficiently deep and land-locked, constitutes a natural harbour for shelter; but for the purposes of commerce, quays, wharfs, and landings must be erected by man. When harbours wholly artificial are to be constructed, excavations have sometimes to be made, but more frequently piers and jetties are built forward into deep water, a certain amount of space enclosed, and breakwaters erected for its protection.

The harbour space is enclosed either by wooden piers or jetties, or stone-walls or dikes. A variety of circumstances have to be taken into account by the engineer before deciding upon the plan of the harbour: he must make himself acquainted with the prevailing currents and winds; the various soundings; and the likelihood there is of the harbour becoming silted up by deposits of shingle or sand brought up by certain currents. In laying down the plan, an important point is to afford the utmost possible facilities for vessels *entering* the port—the reason for this is obvious. The plan of the jetties varies according to circumstances, and to the opinion of the engineer; a usual form is to make the two jetties in curved lines, parallel to one another, the convex sides being in the direction of the currents which bring up deposits of sand or shingle. The opening at the outer end varies also according to local circumstances—it should rarely be less than 300 feet wide. It is usual to make one of the jetties longer than the other, as, nearly on every coast, there is some prevailing wind or current which will influence vessels entering the harbour.

In fig. 25 we give a diagram shewing the usual form of a wooden jetty: *a*, *a*, the piles driven into the ground to form the foundation; *b*, *b*, the cross-pieces; *c*, *c*, the inclined side-pieces; *dd*, the central upright; *e*, *e*, the struts. The upper part is finished with a strong plank flooring, with spaces between the planks to allow of the water passing through. To protect the piles as much as possible, stones or masses of concrete are thrown in at the sides; this filling in being carried up to the level of high spring-tides, where the situation is much exposed. The frames, as shewn in fig. 25, are placed at distances apart according to circumstances, usually from six to ten feet, and are connected together with longitudinal pieces. The great advantages possessed by wooden jetties are cheapness and rapidity of construction; exposed, however, as the timbers are to the ravages of sea-insects and to the action of the waves, they more frequently require repair than jetties constructed of stone. To prevent the ravages of the insects, various means are adopted, which our space will not allow us to notice. (See Practice of Architecture, No. 29.) Stone piers and quays form the most substantial structures; they consist in general of rough rubble, faced seaward with dressed blocks placed on edge, and built slopingly, so

as to present a gradual resistance to the impact of the waves, and finished harbourwards with stone coursings, so as to offer a concave or slightly bevelled wall to the sides of the vessels.

Fig. 26 gives a cross section of a stone-jetty, in which both faces, *c*, *d*, are constructed in coursed ashlar, the heart being filled up with rubble. In some

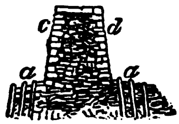


Fig. 26.

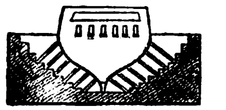


Fig. 27.

cases, it is necessary to protect the foundation with what is called an *apron*, consisting of piles and stones, as at *aa*. Where the sea-face, as *c*, is nearly vertical, the action of the waves is less dangerous than when a long slope is presented to them, as is the case when jetties are constructed after the manner of break-waters—that is, of loose rubble thrown together. In constructing a jetty such as that in fig. 26, the largest stones obtainable should be employed, and means taken to bind the various courses together; the upper surface or roadway being finished with stones carefully dowelled to each other, and so constructed as to throw off readily all water lodging upon it. Quay-walls require to be constructed with great care; to facilitate the discharge of the vessels which lie against them, the more vertical the face of the wall the better, although, for the purposes of stability, it should be inclined. The usual practice, to satisfy both those conditions, is to give a curved outline to both sides of the wall, the outer face being concave. The great difficulties to be overcome in these constructions are—the wet condition of the soil behind the walls, and the yielding bed of mud on which the foundations rest. To obviate the dangers arising from these sources, requires the exercise of great skill on the part of the civil engineer.

The prime objection to harbours enclosed by solid walls and breakwaters, is their liability to be obstructed by deposits of sand, shingle, and other marine silt. Rivers and sewers entering the harbour, the drifting action of the tides and waves, all tend to collect débris; and unless these natural forces be made to counteract each other, or extraneous sluicing and dredging operations be resorted to, both fairway and basin of the finest harbours will in time be rendered useless.

The method which has been generally resorted to for clearing harbours of silt, is the establishment of a powerful current at low-water, proceeding from an inner backwater reservoir capable of being regulated by sluices. This, however, is not found effectual, the silt being generally deposited at the point where the outer current meets that flowing from the harbour. Although the above contrivance is still used in most harbours to a certain extent, dredging-machines are also employed in scooping up, by the power of steam, the mud and shingle, which is emptied into boats, and carried out and deposited in deep water. Another remedy has been proposed—namely, to convert the action of the tides and waves into a sluicing power. This is to be effected by leaving arched openings at frequent intervals in the piers and quays, through which the waters would pass with a force sufficient to scour away every vestige of deposit. It is worthy of note that the ancient Romans adopted this plan on the shores of the Mediterranean.

Docks are inner basins formed in connection with harbours, where vessels may float whatever be the state of the tide in the outer basin, and are generally lined with stone, and provided with appropriate gates or sluices. They are usually described as *wet* to distinguish them from *dry docks*, afterwards referred to. Wet-docks are used for the purpose of loading and unloading; and as they can be completely isolated from other parts of the harbour, every facility is given for warehousing and for conducting the business of the Customs. The level of the water in the docks corresponds with high-water in the harbour or roadstead with which they communicate; consequently, at high-water, ships can enter and leave them, and, if necessary, at low-water they can be sluiced out and cleaned. In tidal rivers, where the range of the tide is great, it would be impossible to conduct a shipping business to any extent without wet-docks; and thus on the Mersey, for example, upwards of a hundred acres of dock, of unparalleled magnificence, have been constructed for the commerce of Liverpool and Birkenhead. The extensive shipping-trade carried on at Glasgow is an example of what may be done in a tidal river without docks, where the difference between high and low water is not so great as it is in the Mersey—although the want of wet-docks has been much felt and is now in course of being supplied.

The construction and operation of dock-locks are very similar to those used in canals, differing only in some points of detail. The gates are worked by means of chains and windlasses; and to enable them to work more freely, and to relieve the quoin post of much of the strain, the mitre post is provided with a metal roller, which runs on a quadrantal iron-way. The width of dock-gates must be such as to admit the largest vessels frequenting the port—docks to admit the large steamers now employed require wider gates than those for sailing-vessels.

Dry or graving docks are constructed so as to admit vessels for the purposes of repair. The sides of the dock are not vertical, but are made to conform somewhat to the contour of the vessel, by being built in a series of steps or set-offs. The dock-gates are constructed in a manner similar to those of the other docks; and on the ship entering at high-water, if the graving-dock opens into a wet-dock, the gates are closed, the water pumped out; and the ship resting on her keel on the bottom of the dock, is shored up and supported by timber, as shewn in fig. 27. By this arrangement, ample space is secured for the workmen carrying on the necessary repairs, and access easily obtained to any part of the contour of the vessel. After the vessel has been repaired, the tide is admitted, the gates are opened, and the vessel floated out. If the graving-docks communicate with the outer or tidal harbour, of course it is not necessary to pump out the water, but merely to close the gates at low-water, which exclude the rising tide.

What are termed *naval docks* are depôts fitted with all sorts of naval stores, and all the requisite machinery for ship-building. The principal naval docks of Great Britain are Portsmouth, Plymouth, Chatham, Sheerness, Woolwich, and Deptford. It is in these docks, and particularly in the first three, that ships-of-war are laid up in time of peace. Vessels can also be conveniently laid dry for repairs by Morton's patent slip, by which the vessel having been allowed to settle down upon a cradle, as the tide falls, is then dragged up an inclined plane by steam-power.

Protection of the Sea-coast.—This is usually effected in Holland, where the most gigantic of such constructions are to be met with, by erecting *dikes* of ordinary earth, of a trapezoidal form in their section. In many places, the top of the dike is little more than three feet above the level of the highest spring-tide. The outer slope, which inclines from three to twelve feet horizontal for one vertical, is finished in a variety of ways, all having the great object in view, of preventing the destructive action of the waves. One plan adopted for this purpose is to cover the face with straw thatch, firmly secured by timbers interlaced with wicker-work, the interstices being filled with stones. This covering is found to resist the action of the waves as well as of currents. Coasts are also protected by fortifying the shore with what are termed *groins*. These are low

erections, which are carried out from the beach in a direction perpendicular or oblique to it, and constructed in various ways, as by throwing up clay and protecting the faces with stones, or by driving piles in juxtaposition—the object being to arrest the current, and cause a settlement of the deposit held in suspension by the water. A very efficient coast-defence has been adopted at Havre, which consists of an embankment having a row of sheeting-piles, with an apron of loose rubble stones. In cases where the sea acts upon a high coast or cliff, and is gradually wearing it away, the only method to insure protection is to build a sea-wall, the face of which should be constructed of large blocks of stone in ashlar courses, well set in hydraulic cement, and the back filled in with concrete or rubble. Every precaution must be taken to prevent the pressure from behind forcing out the wall. The foundation may be protected by an apron of rubble stones at its base.

In carrying out marine works, the engineer will require to study carefully the action of the waves, currents, and the prevailing winds of the locality; the material available for his operations must also be the object of his investigations; nor must he forget that the action of the sea-water will materially influence the permanency of the mortar and cements, and even the stones themselves. This subject has long engaged the attention of engineers and chemists; for it is obvious that if the stones are liable to disintegration, or the mortar or cement rendered useless, it matters not how carefully in other points the works are designed.

On the subject of light-houses, see MARITIME CONVEYANCE.

River improvements have for their object either to deepen the water-way, so as to admit of free navigation, or to protect the banks, and prevent inundations of the surrounding land in time of floods. Space will only allow of our glancing very briefly at these subjects. To deepen the river, it is usually confined between banks, so as to contract the bed. In doing so, it is important to cause as little diversion as possible of the river from its original course. These banks are used to contract the bed at times when the water is low, and are covered with water during floods, as they are generally not higher than the mean level of the river. They may be constructed in a variety of ways—of blocks of stone, of fascines, or of concrete. Fascines are made by tying together a number of twigs placed parallel to one another by other twigs at intervals, according to the diameter.

To protect the ordinary river-banks, and prevent inundations, a variety of plans are adopted. Sometimes a rubble facing is employed; this only, however, where stone is easily obtained, as a large quantity is necessarily required. The banks may also be protected by fascines, as adopted in Holland. These are laid in courses, the small end towards the land, the large towards the water. Each course is set back a short distance from the preceding, forming by this means a regular slope or batter. The whole is finished as already described in the chapter on sea-coast improvements.

Where the action of the current is not very strong, banks are efficiently protected by slopes covered with turf; the smoother the face of these is, the better. The turf, of course, requires to be put on before the usual wet season, to allow of its being consolidated, and bound by vegetation. If any patches get broken, they should be repaired as soon as possible. The height of the banks must be determined by the rise of the river when flooded; and where artificial embankments are required, they should assume the form of long mounds, sloping gradually on both sides. Where a river makes an abrupt bend, the full force of the current sets in towards the concave side, gradually wearing away the bank, unless it is protected, which is generally done either by deflecting the current towards the convex side by the erection of a dike from the concave side, at right angles or obliquely to the current, or by means already described. On the Po, a series of vertical frames are erected, supporting an inclined plane of planks, which has been found effectual.

Where bars are formed by deposits of silt at the mouth of rivers, they may be removed by dredging-machines, or by increasing the force of the current, which is effected by longitudinal dikes in the way already explained. Should the river separate into different small channels at the mouth, dams should be thrown across them, with the exception of one, which should form the main channel; by thus increasing the force of the current, the bed will be kept free from silt. The subsidiary channels should be provided with sluices, so arranged as to freely admit the tide when it is flowing, but closing at the ebb; by this means, all the water will be forced to pass out by the main channel, causing a scour which will clear away any deposits or obstructions laid down by the action of the tides or sea-currents.

We now come to the important subject of the *Supply of Water to Towns*, and *their Drainage*. It is only of late years that the public attention has been directed to the great importance of securing a supply of water, not only for domestic and manufacturing purposes, but to facilitate the discharge of the sewage. Now, however, the subject obtains the full attention it merits, and the various constructions connected with it form one of the most important branches of civil engineering.

The modern methods of supplying towns with water may be divided into two classes: supply by gravitation, and by steam-power; to which may be added artesian wells, a mode of supply much advocated by some engineers, and in a few instances adopted where the circumstances are favourable.

As to the first method, the principle is sufficiently explained in the name. The source is generally at some distance from the town to be supplied, and at a considerable elevation above it. The water is in the first instance led into a large reservoir or a series of reservoirs near the source, the supply being obtained from one or more streams leading into the reservoir. From the large reservoir, the water is conducted through sluices or gates into large cast-iron pipes, which follow the sinuosities of the ground in the most direct line to the town to be supplied. Here it is either stored up in a large reservoir, placed at the highest point of the city, and thence distributed to the districts by means of smaller pipes; or the large town reservoir is dispensed with, and the cast-iron pipes continued into the principal districts, from which smaller pipes branch off as required. Thus, in the following diagram, if *a* represent a lake or reservoir situated in a mountainous district, and *b* a town separated by several

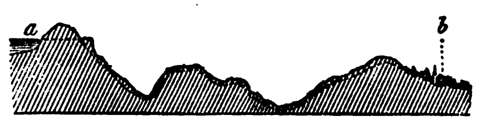


Fig. 28.

miles of irregular country, then on a pipe (indicated by the dotted line) being laid from *a* to *b*, the water will issue with a force sufficient to raise it nearly to the height of the original reservoir—a certain amount of force being lost through friction and atmospheric pressure. Several of our large, and many of our minor towns, are now supplied by this mode; the whole system consisting of the feeding-reservoir—which is generally situated in some hilly district—the line of pipes, with a few air-cocks for the escape of the accumulated air, branches or mains to lead the water into the different districts of the town, and ultimately small service-pipes and cisterns for the houses of the consumers. Wherever practicable, this is by far the most economical and certain method of supplying a town. Manchester, Glasgow, Greenock, Edinburgh, and numerous other places,

are all supplied on this principle. Where the elevation of the source is considerable, the pressure of water in the town pipes is so great as to force the water through jets fixed to them. To these, hose are attached, and the water is used for cleansing the pavements, or for extinguishing fire. Various substitutes have been proposed for cast-iron pipes, as earthenware and glass tubes, &c., but none of them are found so safe and economical as the iron. The iron pipes are made of dimensions suited to the quantity of water to be conveyed, varying from a few inches to three or four feet in diameter. They are joined together by the socket joint, or, as it is sometimes termed, the 'spigot and faucet joint'—the end of one being let into the socket formed at the extremity of the other, the joint being made water-tight by melted lead poured into it. In the improved water-pipes, the end going into the socket is carefully turned, and the interior of the pipe near the socket is bored, so as to produce a perfect joint, when it is lubricated with white-lead.

In designing water-works on the gravitation principle, a variety of points have to be taken into consideration. After deciding as to the situation of the collecting reservoirs—which is generally fixed upon from the presence of a stream or streams at a properly elevated source—the engineer must examine the ground, and ascertain the position of the various tributary streams which are likely to add to the quantity of water; these, with the main stream, must be carefully gauged, and the average daily supply ascertained. He should also consider the likelihood of obtaining supplies by carrying out the thorough drainage of the district, and by opening up of springs, calculating whether the probable expense of this will be repaid by the quantity of water obtained by it. To guide him in these calculations, the indications of the rain-gauge, extending over a comparatively long period, will be of essential service. The next point to be attended to is the construction of the reservoirs. The collecting-reservoirs are usually formed by throwing an embankment across a valley near the source of supply, while the distributing-reservoirs in the towns are generally constructed of masonry. The collecting-reservoirs should be of such capacity as to allow of water equal to some months' consumption to be stored up, and should have reference more to the 'maximum demand and the minimum supply than to the average of either.' The quantity allowed for the inhabitants' consumption may be estimated at twenty-five to thirty-two gallons per head per day; to this must be added the waste from evaporation and leakage. Where the population of a town is rapidly increasing, the reservoirs should be so planned as to admit of extension at a future time. The materials of which the reservoir walls, &c., are constructed should be well considered, as their influence on the stored-up water may be prejudicial. Great care must be taken in the construction of the retaining-walls—for notes on this point, see our remarks in the chapter on Marine Engineering. In some gravitation water-works the water is conveyed in conduits or culverts, as in the Croton water-works which supply New York. Conduits possess many advantages over pipes: the friction is less, and there is less chance of the water-way being choked up by the deposit of saline or chalky matters from the water—an accident which sometimes happens where spring-water is conveyed. Where conduits have to pass hills or rising-grounds, they must be taken through by means of a tunnel, which must be made of such size as to enable the workmen engaged in its construction to proceed with ease in their operations. Where valleys are to be crossed, one of two ways must be employed—conveying the conduit on arches, or forming a reservoir at one side of the valley, leading a pipe or siphon conduit down and along it, and up to another reservoir placed at the other side. Mr Rawlinson advocates the carrying of water across valleys by means of an elevated wrought-iron tube aqueduct—somewhat similar in plan to the aqueduct constructed by Telford for carrying the Chester canal across the Valley of the Dee, in which the water-way is formed of a cast-iron tank, which is now as sound and perfect as the day it was erected. A still cheaper method of conducting water from elevated sources, is by employing open channels, as done by the New River Company in London, and Mr Thom at Greenock. Grave objections may be made to this plan, especially in the neighbourhood of large towns, such as London—the loss from evaporation, the heating of the water, and consequent impetus given to the growth of weeds and insects, the positive contamination of the water through filth thrown into the channel, and the necessity of employing collecting-reservoirs and filter-beds in or near the town, may be noticed here as the most important of these.

In fig. 29 we give a section of the water-works carried

Fig. 29.

into execution at Kilmarnock on the same principle of arrangement as that adopted at the Gorbals Gravitation Water-works, Glasgow. The drawing exhibits the connection of the large reservoir with the self-acting sluices, filter, and pure-water basins. 'By means of the self-acting apparatus which has been adopted, the pure-water basins are kept at the same level, whether the draft at the town be great or small, by first operating on the conduit leading to the filters, and then upon the valve in the pipe leading through the embankment to the lower reservoir—thus making the whole works self-acting, without the intervention of manual labour.'

In all places where there is a deficiency of altitude to carry the water naturally to the highest parts of a town, there is no resource but in the employment of machinery. A steam-engine, or other agent, is applied to the working of pumps, which first draw the water from rivers or wells, and then force it through a train of pipes to all the different points of consumption. This mode is adopted in some of the densest centres of our population—as in London, Liverpool, Glasgow, Aberdeen, Perth, &c.: as, with us, fuel is cheap, and our steam-engines of unrivalled power and construction, pumping as a system is not without its advantages. The original water-works of Glasgow, which are compact and systematically constructed, may be taken as an illustration:—They are situated on the banks of the Clyde (which yields the supply) about two miles above the city, and occupy both sides of the river, the motive-power being on one side, and the aqueducts and filters on the other. The principal aqueduct or filter consists of an elliptical tunnel 7½ feet in diameter, and upwards of 600 yards in length, sunk ten feet lower than the level of low-water, in a bed of sand and gravel, through which the water filters naturally. This tunnel forms a curve parallel with the bed of the river, at about fifty feet from its margin. There are, besides, about eight acres of meadow-land, and nearly two of sand-filter, on which the water is raised by steam-power. The whole water produced by these filters is conveyed through a gravelly subsoil into the tunnel above mentioned. The water thus purified, is brought across the stream through four suction-pipes, laid in the bed of the river, and connected with the engines on the northern side. The water is conveyed into the city through the medium of four principal pipes or *mains*, as they are called, respectively of 14, 21, 25, and 36 inches diameter. As the ground on which Glasgow is built is of great variation of elevation, four intermediate stations or reservoirs have been formed, into which water is raised to the elevation requisite to supply the several districts, and no more; thus economising the power required to be exerted by the steam-engines, and furnishing

at the same time an abundant supply to those who occupy the highest houses.

In fig. 30 we give the section of the Trent Water-works at Nottingham, designed by the well-known engineer Mr Hawksley. 'The water is forced along a main of fifteen inches diameter through the centre of the town, and into a reservoir situated near the park, at an elevation of 135 feet, by a "double-powered" steam-engine of forty horse-power. This principal main supplies various district mains, which again feed the smaller pipes for the supply of the several streets. In these pipes are placed numerous fire-plugs.'


Fig. 30.

The cost of raising water by pumps worked by steam-power is given by Mr Hawksley. To transmit 500 gallons per second, two mains, sixty inches in diameter, will be requisite: to pump this water through pipes twenty-five miles long, into a reservoir 220 feet high, would take a power of 2500 horses, 500 horse-power of this being taken up in overcoming friction. The cost of twenty-five miles of mains would be £1,000,000; of the engines and machinery, £150,000; and of the tanks and reservoirs, £200,000. This calculation is made for London, supposing the water to be taken from the Thames above Windsor—which shews that a first investment of fifteen shillings, or ninepence a head of addition to the annual water-charge, would enable a 'constant supply of the purest soft water to be delivered at all hours, and into every story throughout London.' As a general statement, it may be said that by the use of steam-power from thirty to forty thousand pailfuls of water may be lifted fifty feet high for one shilling. The 'distribution' of the water to the various districts of the town to be supplied, is the same for pump as for gravitation works. Generally speaking, as the water is pumped up from rivers, much contaminating matter is mixed with it. To free it from this, large filtering-reservoirs are necessitated, into which the water is first conveyed—thereafter pumped into the city.

The principle of filtration, and its application to domestic purposes, will be explained in the paper on SUPPLY OF WATER. Filtration on the large scale is generally effected by passing the water through masses of sand or gravel. As the intercepted slime and sediment will in all cases tend to clog and fill up the pores of the filter, considerable ingenuity has been displayed in arranging the materials so as to retard this clogging, and in the construction of what are termed 'self-cleaning' filters. That invented and used by Mr Thom at Greenock, Paisley, Ayr, &c., is one of the most effective, and may be taken in illustration. In the accompanying transverse section, *a* is the conduit for supplying the water to the filter; *c*, a sluice for regulating the flow; *b*, a valve which admits the water above or below the filtering material at pleasure; *c*, a floor of perforated tiles, resting on a puddled basis; *f*, the filter, composed of layers of gravel and sand, gradually increasing in fineness towards the surface, the top layer consisting of fine sand and grained animal charcoal. The whole apparatus being completed, the water is allowed to enter the filter at the top, and passing through the different layers, it issues quite pure and free from taint. When the filter becomes foul, which is shewn by the decreased quality of water passing through, the valve *b* is reversed, and the current made to enter from below, carrying the particles of mud to the surface of the top layer, whence they can be readily removed. Maurra's self-cleansing sand-filter is also ingenious in construction, and efficient in operation, either in the large or small scale.

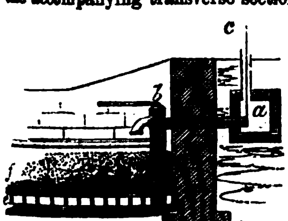


Fig. 31.

In the Gorbals Gravitation Water-works, already alluded to, the plan of filter is as follows:—There are three filtering-beds in duplicate, so that one set can be used while the other is cleaning. These are placed parallel to each other; the first contains a layer of 'sandstone shivers,' into which the water from the reservoir is admitted; flowing through the filtering material in this, the water passes up a hollow wall, which separates one bed from the other, and falls into the second filtering-bed, composed of gravel and sand; from thence through a second hollow wall, into the third filtering-bed of pure sand; and from thence into the pure water-basin, from which it is taken by a main to the town, a distance of nearly six miles. In fig. 32, we give a section of the plan of filter adopted at the Chelsea Water-works. 'A, A, depositing-reservoirs, capable of containing four days' supply; C, C,' inverts formed of open brickwork in cement, used for holding the deposit which is swept into them, and afterwards flushed out with water; B, the filter-bed, shewing the filtering substances, consisting of—1*st*, Coarse gravel, about one foot deep; 2*d*, A stratum of rough screened gravel, nine inches deep; 3*d*, Fine screened gravel, six inches deep; 4*th*, Fine gravel, nine inches; 5*th*, Fine washed gray river-sand, about three feet six inches deep. The water is gradually drawn from the depositing-reservoir on to the surface of the sand, and is allowed to percolate through tunnels formed by bricks with open joints and cement. These lead to other tunnels, which are made of close brick, and lead into the pump-well of the engine.'

Fig. 32.

The most recent improvement or novelty in public water-works is the application of Dr Clark's principle of purification (see SUPPLY OF WATER), which has been adopted by Mr Homersham at the Plumstead, Woolwich, and Charlton Water-works. The quantity of water softened at these works amounts to 600,000 gallons per day. The details connected with the distribution of water, and what may be called the social and domestic features of the question, will be found in the number above referred to, where also is given a description of the principles on which *Artesian* wells are constructed. Space will not allow us to enter into the details of the operations practised; for a description of these, we refer our readers to larger works, under the head Boring of Wells.

The removal of the drainage matters from the neighbourhood of our dwellings is effected by a system of sewers and drains; the former are underground channels of large dimensions, following the line of streets; while the latter are of smaller size, and connect the houses with the central sewer. A well-sewered and drained street, with houses on both sides, resembles in disposition a part of the human frame—the sewer representing the backbone, the drains the ribs. In the present article, we shall glance briefly at that portion of town-drainage to which the attention of the civil engineer is usually directed—namely, the laying down of the main sewers, and the arrangement and construction of their outfalls—leaving those points connected with the house-drains, and which usually fall to the care of the architect and builder, to be discussed in the number on the SUPPLY OF WATER—BATHS, &c.

In commencing the drainage of a town, the first point to be attended to is the outfall or place of final deposit of the drainage matters. Generally, the point chosen is the river which is in the vicinity of most of our towns; the public ideas are, however, becoming much modified on this point; and in view not only of the unhealthiness caused by the practice of polluting our streams, but of the pecuniary loss the community sustains by

throwing away that which is exceedingly valuable for agricultural purposes as a manure, many plans are now being proposed for storing up and treating the sewage matters of towns so as to yield a good manure in the solid form, or to lead it at once in the liquid form to the fields to which it is to be applied (see Irrigation, in AGRICULTURE). The plans for converting the sewage into solid manure are, however, only in contemplation, and it yet remains for the civil engineer to inaugurate successfully and economically a plan of treatment more consistent with sound reason than the one we now so universally adopt. The plan of liquid irrigation has long been adopted with a portion of the drainage of Edinburgh, where extensive meadows in the neighbourhood of the city have been treated in this manner, which has increased the productive powers of the soil to such an extent, that the crops of grass raised upon some of the best portions are annually let at a rental of from £40 to £45 per acre. The whole outlay is the expense of attending to the water-courses, and flooding the surface with the sewage matter at proper intervals, which amounts to a very small sum indeed, compared with the annual returns.

Where the river into which the sewers discharge is a tidal one, the engineer must be careful to arrange the size and position of the outlets so that space may be left for the accumulation of the sewage at times when the tide keeps back the usual flow. Every care must also be taken to make the sewers strong at these points, to resist the extra pressure to which they may be subjected.

The other points claiming the attention of the engineer are the shape, size, and inclination of the sewers. As regards the former, theory, as well as experience, shews that the circular form is the best calculated to assist the flow of the sewage, and prevent deposition of the contained matter. The 'egg-shaped sewer' is allowed on all hands to be the most efficient. In the first place, it is stronger than either the common square conduit with flagged top, or the upright-sided conduit with arched top and bevelled bottom. If the arch-stones are well formed and jointed, no weight or side-pressure can break it down; and if the ground is soft and yielding, the arched structure sinks as a whole. Again, when formed of two rings or courses, as shewn in the section, it is quite impervious either to moisture or effluvia, and requires less concreting and puddling than any other form. It is stated by Mr Roe, whose name is well known in connection with this subject, that with the same flow of water, the liability of the egg-shaped sewer to accumulate solid deposits is diminished one-half, compared with the old upright-sided and flat-bottomed conduit. Lastly, as the oval sewer combines the greatest strength with the smallest consumption of material, a very considerable saving is effected in construction, amounting from two to five shillings per lineal foot over the ordinary upright sewers with footing. Mr Williams has shewn that the saving

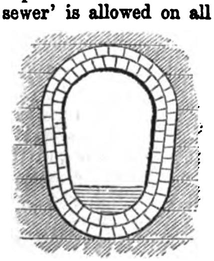


Fig. 33.

in the Westminster district by the construction of the egg-shaped instead of the upright-sided, in ten years, would have been upwards of £66,000.

Where street-sewers are required of small size, egg-shaped earthenware tubes are now used instead of brickwork. In laying these, great care should be taken to bed them well in clay puddling, and to have means here and there to ascertain the state of their interior. In all cases, they should be made very strong, as broken tubes, amounting to a large percentage, are generally found in drainage-works. A plan adopted at Croydon is well adapted to prevent this breakage; it consists in turning a brick arch, half-brick thick over the tubes, which saves them from the superincumbent pressure. The plan adopted by the Romans, of laying the pipes in a bed of pounded brick and mortar, is worthy of imitation. In the remains of some drain-pipes discovered at Zurich, the pipes were found so firmly bedded that pipes and bed formed one mass. All junctions of the house-drains with the sewers should be made of a circular form, never at right angles; because in the latter case, the meeting of the currents produce an eddy which tends to deposit solid matter, creates obstructions in the sewer, and involves considerable expense, as the pavement has frequently to be broken up and relaid, and this independent of the annoyance to the public through the blocking up of the thoroughfare by one of the most disgusting operations. Science at once points out the remedy, by directing the entering channel with a sweep or curve, as shewn in the accompanying diagram.

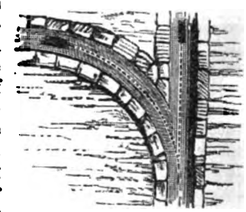


Fig. 34.

In determining the size of the main sewers, the engineer must be guided by the discharge from the houses of the district, so that when the maximum quantity passes through them, it will not fill the sewers more than half full. To the discharge of the sewage-waters of the houses, must be added the waste-water of manufactories; and special note must be taken of the average fall of rain, to allow for the 'storm-waters' of heavy showers. When our town-sewage is used for manure, the rain-fall will be carried from our streets to the river through special drains.

But while every care is taken to obtain a size of sewer well apportioned to the sewage matter which it has to convey, it is of essential importance rather to make it too large than to run into the opposite extreme, and make it too small. A neglect of this precaution may be attended with lamentable results. An investigation into the fever which numbered so many victims a year or two ago at Croydon, Kent, proved that much of the poisonous effluvia which contaminated the atmosphere proceeded from choked-up and broken pipe-sewers, which had been laid down of too small dimensions, and without any provision for ascertaining their condition. The rate of inclination of sewers may be made at one foot of vertical fall for every 100 of horizontal length; it may even be less than this, but should never fall short of 1 foot in 200.

INLAND CONVEYANCE.

THE artificial conveyance of person and property from one locality to another may be treated under two great heads—*Inland* and *Maritime*. To these, science may in time add a third—namely, *Aërial;* but as yet, all the schemes and experiments in this department have been without any available result. Confining our remarks, therefore, to what is real and practicable—roads, rivers, canals, and railways may be regarded as the main channels of inland transport; and the construction of these channels, in so far as artificial, having been discussed in the number on CIVIL ENGINEERING, it remains here to consider the subject in its social and economic aspect, and advert briefly to the history and management of the various modes of conveyance, and their more interesting features as commercial speculations. The consideration of ocean transport is reserved for a subsequent number. As a fitting introduction to our present subject, both in point of information and interest, we may briefly advert to the modes of conveyance adopted by nations but little advanced in the arts of civilisation.

PRIMITIVE MODES OF CONVEYANCE.

The means adopted in early times for artificial transport were, as may be supposed, of the rudest kind, as is still the case in those countries which are little advanced in the useful arts. The most degrading species of conveyance that seems to have been practised, was the employment of human labour in bearing litters or palanquins, specimens of which, on a scale of barbarous splendour, are now seen in India, Burmah, and China.

The first and most obvious improvement in modes of transport was the substitution of brute for human labour; and it is reasonable to conclude that the value of this practice could not have been long in being pressed on the attention of mankind. We find the term 'beasts of burden' used in the most ancient records, the animals meant being the ass, the horse, and the camel. No trace, however, exists of the progress from *burden* to *draught*, though it also must have taken place at a very early period. The ass and horse are equally adapted for carrying or drawing, but the camel exerts its power only by carrying; draught alone is suitable for the reindeer and ox, the backs of these animals being unfit by nature for burden.

Burden.

From the earliest times, the camel, in its two varieties of camel and dromedary—respectively two-hunched and one-hunched—has been employed in the sandy regions of Asia as a beast of burden; and without its invaluable services in this respect, these countries could scarcely have been habitable. In ancient times, it formed the engine of carriage among the merchants of Arabia, and conveyed the products of India across the deserts to the populous and wealthy land of Egypt.

The camel is expressly suited by nature for inhabiting and traversing sandy and parched deserts, in which there are places of rest and refreshment only at wide intervals. 'It is the most temperate of all animals,' says Goldsmith, 'and can continue to travel several days without drinking. In those vast deserts, where the earth is everywhere dry and sandy—where there are neither birds nor beasts, neither insects nor vegetables—where nothing is to be seen but hills of sand and heaps of bones—there the camel travels, posting forward, without requiring either drink or pasture, and is often found six or seven days without any sustenance whatsoever. Its feet are formed for travelling upon sand, and utterly unfit for moist or marshy places; the inhabitants, therefore, find a most useful assistant in this animal, where no other could subsist, and by its means cross those deserts with safety which would be impassable by any other method of conveyance.

'Camels are easily instructed in the methods of taking up and supporting their burdens; their legs, a few days after they are produced, are bent under their belly; they are in this manner loaded, and taught to rise; their burden is every day thus increased, by insensible degrees, till the animal is capable of supporting a weight adequate to its strength. The same care is taken in making them patient of hunger and thirst: while other animals receive their food at stated times, the camel is restrained for days together, and these intervals of famine are increased in proportion as the animal seems capable of sustaining them. By this method of education, they live five or six days without food or water; and their stomach is formed most admirably by nature to fit them for long abstinence. Besides the four stomachs which all animals have that chew the cud—and the camel is of the number—it has a fifth stomach, which serves as a reservoir to hold a greater quantity of water than the animal has an immediate occasion for. It is of sufficient capacity to contain a large quantity of water, where the fluid remains without corrupting, or without being adulterated by the other aliments. When the camel finds itself pressed with thirst, it has here an easy resource for quenching it: it throws up a quantity of this water, by a simple contraction of the muscles, into the other stomachs, and this serves to macerate its dry and simple food.

'In Turkey, Persia, Arabia, Barbary, and Egypt, the whole commerce is carried on by means of camels; and no carriage is more speedy or less expensive in these countries. Merchants and travellers unite themselves into a body, furnished with camels, to secure themselves from the insults of the robbers that infest the countries in which they live. This assemblage is called a *caravan*, in which the numbers are sometimes known to amount to above 10,000, and the number of camels is often greater than that of the men. Each of these animals is loaded according to his strength, and he is so sensible of it himself, that when his burden is too great, he remains still upon his belly, refusing to rise till his burden be lessened or taken away. In general, the larger camels are capable of carrying 1000 pounds' weight, and sometimes 1200; the dromedary from 600 to 700. In these trading journeys, they travel but slowly; their stages are generally regulated, and they seldom go above thirty, or at most about thirty-five miles a day. Every evening, when they arrive at a stage, which is usually some spot of verdure where water and shrubs are in plenty, they are permitted to feed at liberty; they are then seen to eat as much in an hour as will supply them for twenty-four. They seem to prefer the coarsest weeds to the softest pasture—the thistle, the nettle, the cassia, and other prickly vegetables are their favourite food; but their drivers take care to supply them with a kind of paste composition, which serves as a more permanent nourishment. As these animals have often gone the same track, they are said to know their way precisely, and to pursue their passage when their guides are utterly astray. When they come within a few miles of their baiting-place in the evening, they sagaciously scent it at a distance, and increasing their speed, are often seen to trot with vivacity to their stage.

'The patience of this animal is most extraordinary;

and it is probable that its sufferings are great, for when it is loaded, it sends forth most lamentable cries, but never offers to resist the tyrant that oppresses it. At the slightest sign, it bends its knees, and lies upon its belly, suffering itself to be loaded in this position: by this practice, the burden is more easily laid upon it than if lifted up while standing. At another sign, it rises with its load, and the driver getting upon its back, between the two panniers—which, like hampers, are placed upon each side—he encourages the camel to proceed with his voice and with a song. In this manner the creature proceeds contentedly forward, with a slow uneasy walk of about four miles an hour, and when it comes to its stage, lies down to be unloaded.'

From Major Skinner's account of his *Journey to India*, in the course of which he travelled twenty days with a numerous caravan from Damascus to Bagdad, we have the following lively picture of the mode of conveyance by camels:

'I must give a description of our equipage, now that we are fairly launched on the great waste. I ride a white camel, with my saddle-bags under me, and a pair of water-skins, quite full, beneath them: over the saddle is my bed. A thick cherry-stick, with a cross at the end of it, serves to guide the animal: a gentle tap on the side of his neck sends him to the left, and one on the opposite makes him turn back again to the right: a knock on the back of his head stops him, and a few taps between the ears bring him to his knees, if accompanied by a guttural sound, resembling, as the Arabs say, the pronunciation of their letter *sche*. To make him move quickly, it is necessary to prick him with the point of the stick.

'We passed over a perfect level this morning, strewed with flowers and thick with pasture for the camels, where we are now resting. It is not usual here, as in many parts of the East, for the camels to wind in long strings, one after the other. Our numbers, amounting to 1500, are scattered over the surface in all directions, as far as the eye can trace. In travelling, the sheiks, or chiefs of the caravan, attended by the military part of their equipage, mounted on dromedaries, move in advance, while the loaded camels follow at some distance, in parallel masses, opening out, or changing the form, as the grass renders it necessary. They fall so naturally into military figures, that it is difficult to conceive their doing it without direction. We have several tents in the caravan. They are pitched so as to permit the camels belonging to each to lie in the intervals, where they are placed in *squads* for the night. They are by no means agreeable neighbours; for although they are not able to move from their place, they make a most unpleasant gurgling noise.

'The rate at which a loaded camel travels is estimated at two and a half miles an hour by almost every traveller. Our caravan has not, I think, exceeded this; but the variety of its movements has been very tiresome. There is so strong a resemblance to a voyage at sea in a passage across the desert, that I cannot divest myself of the belief that the moving mass is but a collection of small vessels, carried into a heap by the tide. Every man is ready with his stick to fend off the animal that approaches him: one push separates the camels, as it would separate a couple of boats; and they move away, quite unconscious of the circumstance, till another movement swings them together again.'

Turning to the new world, we find, from the remotest period to which the Peruvian records extend, that the aborigines not only used the llama and alpaca for food and clothing, but also employed them in their military and domestic service, as the Arabs do the camel. The llama was principally destined to carry burdens, although, compared with the Asiatic drudge, the difference in size and strength is considerable. Its load, according to Mr Walton, never exceeded 150 pounds, with which it was not required to travel more than three leagues per day; whereas in the working part of the twenty-four hours, the camel journeys double that distance with 800 pounds or more upon his back. For this difference the Peruvians made up in the greater number of their beasts of burden, one drove sometimes exceeding 500 head, whose subsistence on the road was entirely left to chance. Neither whip nor goad was used to urge them on: one llama, older and more experienced than the rest, led the way, the others following irregularly but quietly after. Owing to its docility and knowledge of its keeper, this animal evidently requires less training than the camel. It needs no rein—not even a packsaddle—so long as the panniers or packages are well poised.

We need scarcely advert to the fact, that wherever civilisation has made any progress, the horse, the ass, and their hybrid the mule, have been used as beasts of burden—that is to say, in those countries which form their natural habitats. At what period the horse was first subjected to the purposes of man, we have no authentic record. He is mentioned by the oldest writers, and it is probable that his domestication was nearly coeval with the earliest state of society. Trimmed and decorated chargers appear on Egyptian monuments more than four thousand years old; and on sculptures equally, if not more ancient, along the banks of the Euphrates. One of the oldest books of Scripture contains the most powerful description of the war-horse; Joseph gave the Egyptians bread in exchange for horses; and the people of Israel are said to have gone out under Joshua against hosts armed with 'horses and chariots very many.' At a later date, Solomon obtained horses 'out of Egypt, and out of all lands,' and had 'four thousand stalls for horses and chariots, and twelve thousand horsemen.' Thus we find that in the plains of the Euphrates, Nile, and Jordan, the horse was early the associate of man, bearing him with rapidity from place to place, and aiding in the carnage and tumult of battle. He does not appear, however, to have been employed in the more useful arts of agriculture and commerce; these supposed drudgeries being imposed on the more patient ox, ass, and camel. Even in refined Greece and Rome, he was merely yoked to the war-chariot, placed under the saddle of the soldier, or trained for the race-course. As civilisation spread westward over Europe, the demands upon the strength and endurance of the horse were multiplied, and in time he was called upon to lend his shoulder indiscriminately to the carriage and wagon, to the mill, plough, and other implements of husbandry. It is in this servant-of-all-work capacity that we must now regard him; and certainly a more docile, steady, and willing assistant it is impossible to find. For burden, the ass perhaps is more steady and enduring; but both are surpassed by the mule, which in Spain, South America, Mexico, and other countries destitute of good roads, affords one of the most available modes of commercial transport. Headed by one of superior sagacity, they move in long cavalcades, like the camel and llama, and with their gay caparisons, tinkling bells, and jauntily-dressed drivers, form a very picturesque object in the landscape.

Another primitive mode of carriage, and the last which we shall mention, is the employment of the huge and unwieldy but powerful elephant. At what time this animal was first subjugated, and trained to take part in the court and military equipage of the East, we have no means of knowing. His form appears on the most ancient Hindoo sculptures; he figures in their mythology; and he is spoken of with pride and veneration in their earliest records. In that fertile and luxurious region, he had been trained for centuries before the names of Greece and Rome were known, and even long before the people of Western Asia had passed from the primitive or pastoral condition. It was to Alexander the Conqueror that the western world

was first indebted for the elephant; he it was that made the sports of Persia and India familiar to the Greeks and Macedonians. The acquisition of the war-elephant gave new pomp and splendour to his squadrons, and his example was followed by degrees by other nations. In time, the Egyptians, Carthaginians, Romans, all made use of elephants, both to assist in the march, by carrying enormous loads of baggage, and to join the ranks, mounted by numbers of archers and spearmen, as here represented.

Since the introduction of firearms and artillery, the war-elephant has been greatly abandoned even in the East, and is now chiefly used in carrying baggage, in doing other heavy work, and, above all, in adding to the 'pomp and circumstance' of Oriental authority. The present employment of the elephant in India, according to Von Orlich and other recent writers, is exceedingly varied—from the piling of firewood and the drawing of water, to the dragging of artillery and the carriage of royalty. When placed under the *howdah*—a covered seat for persons of rank—his back is protected by a thickly stuffed hair-cushion, over which is spread an ornamental covering. The howdah is made to contain two persons, and this is the amount of the travelling elephant's burden. The driver sits on his neck, immediately behind his ears, and guides him with an iron prong; and he is in general so docile, as to kneel for the parties to mount him. His great use, however, is as a beast of burden in a country where there are few or no roads; and since an ordinary elephant will carry as much as five camels, we can readily perceive his value in marching not only with the commanders and sick, but with the tents and furniture. He is equally serviceable as a beast of draught, pulling with ease what it would take ten horses to move; and it is for this reason that the Indian army have yoked him to their heavy artillery. Another power which the animal possesses, and one which is unknown to the horse or ox, is that of pushing; and if his forehead be protected by a pad, he will push forward weights which perhaps he could not draw. These, and many other duties, the elephant performs willingly, and, if gently treated and well fed, with a regularity of disposition which seems almost mechanical.

Draught.

The draught of the reindeer is employed in Lapland as the chief means of artificial locomotion, and is always exerted on a species of sledge, which, by its form, is suitable for gliding easily over the frozen ground or snow. The shape of the sledge somewhat resembles a small boat with a sharp prow, and flat in the rear, against which the inmate of the vehicle rests. The traveller is swathed in his carriage like an infant in a cradle, with a stick in his hand to steer the vessel, and disengage it from pieces of rock or stumps of tree that may happen to obstruct the route. He must also balance the sledge with his body, otherwise he will be in danger of being overturned. The traces by which this carriage is fastened to the reindeer are fixed to a collar about the animal's neck, and run down over the breast, between the fore and hind legs, to be connected with the prow of the sledge; the reins, managed by the traveller, are tied to the horns; and the trappings are usually furnished with little bells, the sound of which is agreeable to the animal. With this draught, the reindeer, if pressed, will travel from sixty to eighty miles in a day; but more frequently he does not travel more than forty or fifty, which is a good day's journey. Before he sets out, the Laplander whispers in his ear the way he has to go, and the place at which he has to halt, firmly persuaded that the beast understands his meaning. In the beginning of winter, the Laplanders strew fir-boughs to mark the most frequented paths; and the successive layers of fresh snow being pressed down by the sleighs, a firm causeway of snow comes to be formed, which is the more smooth if the surface has felt a partial thaw, and been crusted by a subsequent frost. It requires great caution to follow these tracks; for if the carriage deviates to the right or left, the traveller is plunged into an abyss of snow. In less frequented parts, where there is no such beaten road, the Laplander directs his course by certain marks made on the trees.

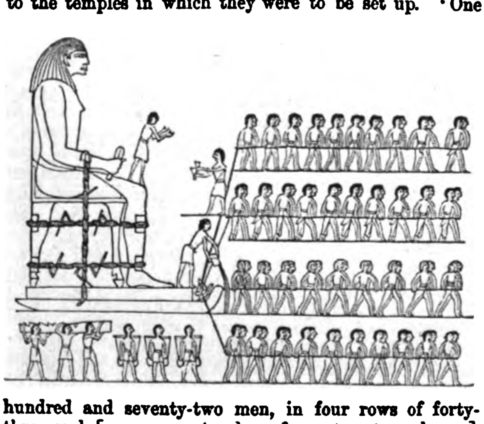
Among the Kamtschatdales, Esquimaux, and other northern tribes, a peculiar variety of dog is almost universally employed as a beast of draught, and occasionally as one of burden. These animals are trained to draw the rude sledges that the Esquimaux, for example, are able to construct, which are about five feet long and two wide. The runners are generally made of pieces of wood and bone lashed together, with the interstices stuffed with moss, and the whole secured by a coating of ice, which is readily produced by the severity of the climate. The runner is shod with a plate of hard bone, and water is poured over this, to form another coating of ice, which is renewed as often as it is worn off—a mode of shoeing which serves very well for nearly eight months out of the twelve. The dogs are harnessed by a collar, and a single trace running over their backs. They are not tied to each other, but each one is attached separately to the sledge, and at unequal distances, some even at twenty feet. The most docile dog is the leader, and his is the longest trace. A good leader is very attentive to the words of the conductor, and looks back over his shoulder with great earnestness to catch the word of command. Ten dogs make a full team, and will draw a sledge twelve miles an hour; and nine of them have been known to draw 1611 pounds a mile in nine minutes. Three dogs drew Captain Lyon, in a sledge weighing 100 pounds, a mile in six minutes. On a good surface, six or seven dogs will perform in a day a journey of sixty miles, with nearly 1000 pounds to draw. When there is no snow, the dogs are sometimes made to carry burdens in a kind of panniers, and one will travel thus with twenty-five pounds.

In Russia, and also in Canada, sleighs are used in winter for conveyance from place to place, the beast of draught being the horse. As the roads in many parts of Canada are very unsuitable for any species of travelling, it happens that sleighing over the hardened surface of the snow in winter is by far the best mode of communication in that country. It is almost unnecessary to add, that the sledge, which is the rudest kind of carriage for draught, has disappeared in all countries considerably advanced in improvement.

From the rude sledge, drawn with an incalculable degree of labour over the rough ground, the next important step in mechanical construction is to apply wheels, for the purpose of lessening the friction of the moving body. The first application of wheels to carriages is

beyond the reach of record. Wagons are spoken of in the book of Genesis, from which it may be inferred that a knowledge of wheels was common in a very early age. It is further known that the making of wheels formed a distinct trade among the citizens of Thebes in ancient Egypt, three or four thousand years ago. The most elegant of the Egyptian carriages was a kind of gig, or light open chariot, on two wheels, called the *plaustrum*, which is thus described by Mr Wilkinson in his work on the *Manners and Customs of the Ancient Egyptians:* 'The plaustrum was very similar to the war-chariot and the curricle, but the sides appear to have been closed, and it was drawn by a pair of oxen instead of horses. The harness was much the same, and the wheels had six spokes. In a journey, it was occasionally furnished with a sort of umbrella, fixed upon a rod rising from the centre or back of the car; the reins were the same as those used for horses, and apparently furnished with a bit; and besides the driver, a groom or runner sometimes attended on foot, at the head of the animals, perhaps feeding them as they went. The annexed engraving represents an Ethiopian princess, who is on her journey through Upper Egypt to Thebes, where the court then resided.'

From the researches of the same authority, we are enabled to form some estimate of the enormous trouble incurred by the ancient Egyptians in the transport of the heavy stones which they employed in building their temples. Some of these blocks weighed three or four thousand tons, and were usually conveyed from the quarries from which they were cut in flat-bottomed boats on canals made for the purpose. Occasionally, however, when this mode of transport was unsuitable, the stone was drawn on sledges, perhaps some hundreds of miles, by oxen, or by human labour. The accompanying wood-cut represents, in an abridged form, the mode of conveying colossal figures in stone from the quarries to the temples in which they were to be set up. 'One



hundred and seventy-two men, in four rows of forty-three each [we represent only as far as twenty each row], pull the ropes attached to the front of the sledge; and a liquid, probably grease, is poured from a vase by a person standing on the pedestal of the statue, in order to facilitate its progress as it slides over the ground, which was probably covered with a bed of planks, though they are not indicated in the painting. Some of the persons employed in this laborious duty appear to be Egyptians, the others are foreign slaves, who are clad in the costume of their country. Below are persons carrying vases of the liquid, or perhaps water, for the use of the workmen, and some implements connected with the transport of the statue, followed by taskmasters with their wands of office [but which we have not had space to include]. On the knee of the figure stands a man, who claps his hands to the measured cadence of a song, to mark the time, and insure their simultaneous draught. The height of the statue appears to have been about twenty-four feet, including the pedestal. It was bound to the sledge by ropes, which were tightened by means of pegs inserted between them, and twisted round until completely braced; and to prevent injury from the friction of the ropes upon the stone, a compress of leather or other substance was introduced at the part where they touched the statue.' Besides the great number of persons employed in drawing these huge blocks, it was customary for a band of some hundreds of soldiers to attend, perhaps for the purpose of overawing the slaves, and compelling obedience in their odious task. A more degrading means of mechanical conveyance, it would be impossible to represent.

TRAVELLING IN PAST TIMES IN BRITAIN.

The modes of travelling and conveyance in Britain were of a comparatively rude and primitive kind till the latter part of the seventeenth century; and anything like comfortable and quick travelling cannot be said to have been known till a century later, when mail-coaching was introduced. In old times, people of a humble rank travelled only on foot, and those of a higher station on horseback. Noblemen and gentlemen, as much for ostentation as use, kept running-footmen—a class of servants active in limb, who ran before them on a journey, or went upon errands of special import. The pedestrian powers of these footmen were often surprising. For instance, in the Duke of Lauderdale's house at Thirlstane, near Lauder, on the table-cloth being one morning laid for a large dinner-party, it was discovered that there was a deficiency of silver spoons. Instantly the footman was sent off to the duke's other seat of Lethington, near Haddington, fully seventeen miles off, and across hills and moors, for a supply of the necessary article. He returned with a bundle of spoons in time for dinner. Again—at Hume Castle, in Berwickshire, the Earl of Home had one night given his footman a commission to proceed to Edinburgh (thirty-five miles off), in order to deliver a message of high political consequence. Next morning early, when his lordship entered the hall, he saw the man sleeping on a bench, and conceiving that he had neglected his duty, was about to commit some rash act, when the poor fellow awoke, and informed Lord Home that his commission had been executed, and that, having returned before his lordship was stirring, he had only taken leave to rest himself a little. The earl, equally astonished and gratified by the activity of his faithful vassal, rewarded him with a little piece of ground, which to this day bears the name of the *Post Rig*—a term equivalent to the postman's field, and an unquestionable proof, as all the villagers at Hume devoutly believe, of the truth of the anecdote. The custom of keeping a running-footman did not cease, amongst noble families in Scotland, till towards the middle of the last century.

When the matter of communication was of particular importance, or required to be despatched to a considerable distance, horsemen were employed; and these, by means of relays of fresh animals, and great toil of body,

would proceed journeys of some hundreds of miles to accomplish what would now be much better done by a post letter. Some journeys performed on horseback in former days would be considered wonderful even in modern times, with good roads. Queen Elizabeth died at one o'clock of the morning of Thursday the 24th of March 1603. Between nine and ten, Sir Robert Carey left London—after having been up all night—for the purpose of conveying the intelligence to her successor James at Edinburgh. That night he rode to Doncaster, 155 miles. Next night he reached Witherington, near Morpeth. Early on Saturday morning he proceeded by Norham across the Border; and that evening, at no late hour, kneeled beside the king's bed at Holyrood, and saluted him as king of England, France, and Ireland. He had thus travelled 400 miles in three days, resting during the two intermediate nights. But it must not be supposed that speed like this was attained on all occasions. At the commencement of the religious troubles in the reign of Charles I., when matters of the utmost importance were debated between the king and his northern subjects, it uniformly appears that a communication from Edinburgh to London, however pressing might be the occasion, was not answered in less than a fortnight. The crowds of nobles, clergymen, gentlemen, and burghers, who at that time assembled in Edinburgh to concert measures for opposing the designs of the court, always dispersed back to their homes after despatching a message to King Charles, and assembled again a fortnight thereafter, in order to receive the reply and take such measures as it might call for. And even till the last century was pretty far advanced, the ordinary riding post between London and Edinburgh regularly took a week to the journey.

In consequence of the inattention of our ancestors to roads, and the wretched state in which these were usually kept, it was long before coaching of any kind came much into fashion. Though wheeled vehicles of various kinds were in use among the ancients, the close carriage or coach is of modern invention. The word *coach* is Hungarian, and the vehicle itself is supposed to have originated in Hungary. Germany certainly appears to have taken the precedence of the nations of Western Europe in using coaches. They were introduced thence into England some time in the sixteenth century, but were, after all, so little in vogue throughout the whole reign of Elizabeth, that there is no trace of her having ever used one. Lord Grey de Wilton, who died in 1593, introduced a coach into Ireland, the first ever used in that country. One was introduced into Scotland—we rather think from France—about the year 1571. It belonged to the famous Secretary Maitland of Lethington, who, during the horrid civil war between the adherents of Mary and those of her son James, made a journey in that vehicle from Edinburgh Castle, which he was holding out for the queen, to Niddry in West Lothian, for the purpose of consulting with some others of her friends—the first time, it is believed, that a close carriage was ever used in Scotland. Fynes Morison, who wrote in the year 1617, speaks of coaches as recently introduced, and still rare in Scotland. For a long time these conveniences were only used by old people, who could not well bear riding. The young and active despised them, as tending to effeminacy, and as not being so quick of movement as the horse. The Duke of Buckingham, in 1619, first used a coach with six horses—a piece of pomp which the Duke of Northumberland thought proper to ridicule by setting up one with eight. Charles I. was the first British sovereign who had a state-carriage. Although Henri IV. was killed in a coach—the only one, by the way, he possessed—his ordinary way of appearing in the streets of Paris was on horseback, with a large cloak strapped on behind, to be used in case of rain. In Scotland, previous to the civil war, coaches were only used by persons of high estate.

In a pamphlet called *The Grand Concern of England Explained*, published in 1673, the writer very gravely attempts to make out that the introduction of coaches was ruining the trade of England. The following is an example of his mode of reasoning:—'Before the coaches were set up, travellers rode on horseback, and men had boots, spurs, saddles, bridles, saddle-cloths, and good riding-suits, coats and cloaks, stockings and hats, whereby the wool and leather of the kingdom were consumed. Besides, most gentlemen, when they travelled on horseback, used to ride with swords, belts, pistols, holsters, portmanteaus, and hat-cases, which in these coaches they have little or no occasion for. For when they rode on horseback, they rode in one suit, and carried another to wear when they came to their journey's end, or lay by the way; but in coaches, they ride in a silk suit, with an Indian gown, with a sash, silk stockings, and the beaver hats men ride in, and carry no other with them. This is because they escape the wet and dirt which on horseback they cannot avoid; whereas in two or three journeys on horseback, these clothes and hats were wont to be spoiled; which done, they were forced to have new very often, and that increased the consumption of manufacture. If they were women that travelled, they used to have safeguards and hoods, side-saddles and pillions, with strappings, saddle or pillion cloths, which, for the most part, were laced and embroidered; to the making of which there went many several trades, now ruined.' But the writer has other reasons to urge against coach-travelling. 'Those who travel in this manner,' he observes, 'become weary and listless when they ride a few miles, unwilling to get on horseback, and unable to endure frost, snow, or rain, or to lodge in the fields.' Besides, he asks, 'what advantage can it be to a man's health to be called out of bed into these coaches an hour or two before day in the morning?—to be hurried in them from place to place till one, two, or three hours within night; insomuch that, after sitting all day, in the summer time, stifled with heat and choked with dust—or in the winter time, starving or freezing with cold, or choked with filthy fogs, they are often brought into their inns by torch-light, when it is too late to sit up to get supper, and next morning they are forced into the coach so early, that they can get no breakfast? What addition is it to men's health or business to ride all day with strangers, oftentimes sick, ancient, diseased persons, or young children crying; all whose humours he is obliged to put up with, and is often poisoned with their nasty scents, and crippled with boxes and bundles? Is it for a man's health *to be laid fast in the foul ways, and forced to wade up to the knees in mire; afterwards* sit in the cold till teams of horses can be sent to pull the coach out? Is it for their health to travel in rotten coaches, and to have their tackle, or perch, or axle-tree broken; and then to wait three or four hours (sometimes half the day), and afterwards to travel the whole of the night to make good their stage?'

These, however, do not exhaust the patriotic clamours of the writer against the odious innovation of stage-coaching. He says that the practice 'discourages the breed of horses,' an argument which, it is amusing to observe, has also been used in opposition to the introduction of railways in recent times. In certain very peculiar circumstances, he allows, stage-coaching might be tolerated, but in no other. 'If some few stage-coaches were continued—to wit, one to every shire-town in England, to go once a week backward and forward, and to go through with the same horses they set forth with, and not travel above thirty miles a day in the summer, and twenty-five in the winter, and to shift inns every journey, that so trade might be diffused—these would be sufficient to carry the sick and the lame, that they pretend cannot travel on horseback; and being thus regulated, they would do little or no harm; especially if all be suppressed within fifty miles of

London, where they are noway necessary, and yet so highly destructive.'

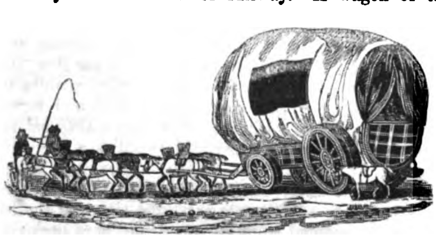
We have thought fit to introduce these extracts here, not so much for the purpose of amusing the reader with their absurdity, as to afford a caution to the general opponents of improvement. Arguments of a similar illogical nature are now used in reference to almost every proposed melioration in our social condition, and will doubtless, in a century hence, be quoted for their short-sighted folly, though at present meeting with countenance from a large class of the community.

Notwithstanding the introduction of stage-coaches in the seventeenth century, they were placed only on the principal roads, and used almost exclusively by persons of refined taste and wealth. The popular mode of conveyance continued for at least a century afterwards to be by stage-wagons; these were very large and cumbersome machines, drawn by six or eight horses, and devoted chiefly to the carriage of goods to and from the metropolis. The only part of the vehicle which afforded accommodation to passengers was the tail of the wagon, as it was called, a reserved space with a hooped-up cover at the hinder part of the machine; and here, sitting upon straw as they best could, some half-dozen passengers were slowly conveyed—we should rather say jolted—on their journey.

The wagons thus employed in the double office of carrying both goods and passengers were, as we have said, confined chiefly to the great lines of road in England. On all the less-important routes, and particularly in Scotland, the only means of conveyance for goods was by packhorses. These animals were loaded with sacks

thrown across the back; and if not too heavy, piled to a considerable height. A number together were generally conducted in a line along the narrow and badly constructed paths, that which went before carrying a bell, by the tinkling sound of which the cavalcade was kept from straggling after nightfall. This primitive mode of conveyance continued in operation in some parts of the country till the year 1780 or thereabouts, when one-horse carts came into use.

The old-fashioned wagons still remain in use in England, notwithstanding the numerous improvements in modes of conveyance and locomotion. They are chiefly employed for the carriage of goods between the metropolis and country towns which are at a distance from any line of canal or railway. A wagon of this



kind is provided with four broad and huge wheels, and is drawn by six large horses, the driver sometimes riding on a separate small pony. The wagons employed in London to convey coal from the wharfs to the houses of consumers, or beer from brewers, are of the same unwieldy form, and are drawn with a needless expenditure of power. Railway traffic, however, is now rapidly diminishing the number of these ponderous vehicles; and the desire for increased speed is as rapidly substituting, on all the common roads, light and elegant spring-vans.

The length of time consumed in journeys by even the best kind of carriages of past times, is now matter for surprise. The stage-coach which went between London and Oxford in the reign of Charles II., required two days, though the space is only fifty-eight miles. That to Exeter (168½ miles) required four days. In 1703, when Prince George of Denmark went from Windsor to Petworth to meet Charles III. of Spain, the distance being about forty miles, he required fourteen hours for the journey, the last nine miles taking six. The person who records this fact says, that the long time was the more surprising, as, *except when overturned*, or when stuck fast in the mire, his royal highness made no stop during the journey.

In 1742, stage-coaches must have been more numerous in England than in Charles II.'s time; but it does not appear that they moved any faster. The journey from London to Birmingham (116 miles) then occupied nearly three days, as appears from the following advertisement:—'The Lichfield and Birmingham stage-coach set out this morning (Monday, April 12, 1742) from the Rose Inn, Holborn Bridge, London, and will be at the Angel, and the Hen and Chickens, in the High Town, Birmingham, on Wednesday next, to dinner; and goes the same afternoon to Lichfield. It returns to Birmingham on Thursday morning to breakfast, and gets to London on Saturday night; and so will continue every week regularly, with a good coach and able horses.' Thus the whole week was occupied in a journey to and from Lichfield by Birmingham, an entire space of probably not more than 240 miles—that is, at an average of forty miles a day.

Of the stage-coach journey to Bath about 1748, we learn some particulars from Smollett's celebrated novel. Mr Random enters the coach before daylight. It proceeds. A highwayman attacks it before breakfast, and is repulsed by the gallantry of the hero. Strap meanwhile accompanies the coach on horseback. A night is spent on the road, and the journey is finished next day, apparently towards evening—108 miles! At that time there was no regular stage-coach from London to Edinburgh; and the newspapers of the latter city occasionally present advertisements, stating that an individual about to proceed to the metropolis by a post-chaise would be glad to hear of a fellow-adventurer, or more, to lessen the expenses for mutual convenience. However, before 1754, there was a stage-coach between the two British capitals. In the *Edinburgh Courant* for that year, it is advertised that—'The Edinburgh stage-coach, for the better accommodation of passengers, will be altered to a new genteel two-end glass coach machine, hung on steel springs, exceeding light and easy, to go in ten days in summer and twelve in winter; to set out the first Tuesday in March, and continue it, from Hosea Eastgate's, the Coach and Horses in Dean Street, Soho, London, and from John Somerville's in the Canongate, Edinburgh, every other Tuesday, and meet at Burrowbridge on Saturday night, and set out from thence on Monday morning, and get to London and Edinburgh on Friday. In winter, to set out from London and Edinburgh every other [alternate] Monday morning, and to go to Burrowbridge on Saturday night; and to set out from thence on Monday morning, and get to London and Edinburgh on Saturday night. Passengers to pay as usual. Performed, if God permits, by your dutiful servant, HOSEA EASTGATE.' Here the distance of 200 miles requires six days in winter, being

at the rate of little more than thirty-three miles a day. So lately as the end of the last century, the journey by the stage between Edinburgh and Glasgow (forty-two miles) occupied a whole day, the passengers stopping to dine on the road. It was considered a great improvement when, in 1799, a coach was started with four horses, which performed the journey in six hours. It is not unworthy of being noticed, that when the mail-coaches were started by Mr Parker in 1788, six and a half miles an hour was the utmost speed attained.

ROADS.

It will appear, from the preceding notices respecting travelling and modes of carriage for goods, that little or no improvement could be expected in either case till a great change for the better was made on the state of the roads. In no branch of art do our ancestors seem to have been more deficient or heedless than in that of making roads, and keeping them in constant repair. In this respect, indeed, they were in a condition of greater ignorance than the ancient Romans, whose roads were on the most extensive and efficient scale, suitable to the necessities of the period, and may here be shortly described.

Ancient Roman Roads.

It is, we believe, generally allowed that the Romans gained a certain degree of knowledge on the subject of road-making from Greece and Carthage, and also perhaps from Egypt; but whatever they learned, they greatly improved upon, and therefore they are entitled to be called the first and best road-makers of whom history has preserved any account. One great leading principle actuated the Roman authorities in establishing roads: it was that of maintaining their military conquests. On vanquishing a barbarous country, their first efforts consisted in penetrating it with good roads, which were maintained with jealous care, and were connected, as far as possible, in unbroken and direct lines with the seat of government at Rome: this indeed formed one of their grandest ensigns of subjugation, and affords us a striking proof of their sagacious and active character.

Speaking of the subordinate Roman capitals in Asia Minor, Syria, and Egypt, Gibbon describes as follows the manner in which they were connected by roads: 'All these cities were connected with each other and with the capital by the public highways, which, issuing from the Forum at Rome, traversed Italy, pervaded the provinces, and were terminated only by the frontiers of the empire. If we carefully trace the distance from the wall of Antoninus [in Scotland] to Rome, and from thence to Jerusalem, it will be found that the great chain of communication, from the north-west to the south-east point of the empire, was drawn out to the length of 4080 Roman [or 3740 English] miles. The public roads were accurately divided by mile-stones, and ran in a direct line from one city to another, with very little respect for the obstacles either of nature or private property. Mountains were perforated, and bold arches thrown over the broadest and most rapid streams. The middle part of the road was raised into a terrace which commanded the adjacent country, consisting of several strata of sand, gravel, and cement, and was paved with large stones, or in some places near the capital, with granite. Such was the solid construction of the Roman highways, whose firmness has not entirely yielded to the effect of fifteen centuries. They united the subjects of the most distant provinces by an easy and familiar intercourse; but their primary object had been to facilitate the marches of the legions: nor was any country considered as completely subdued, till it had been rendered in all its parts pervious to the arms and authority of the conqueror. The advantage of receiving the earliest intelligence, and of conveying their orders with celerity, induced the emperors to establish throughout their extensive dominions the regular institution of posts. Houses were everywhere erected, at the distance of only five or six miles; each of them was constantly provided with forty horses; and by the help of these relays, it was easy to travel a hundred miles in a day along the Roman roads. The use of the posts was allowed to those who claimed it by an imperial mandate; but though originally intended for the public service, it was sometimes indulged to the business or conveniency of private citizens.'

From other accounts, we learn that the Roman roads varied in importance and uses. The great lines were called *prætorian ways*, as being under the direction of the prætors; and these formed the roads for military intercourse. Other lines were exclusively adapted for commerce or civil intercourse, and were under the direction of consuls. Both kinds were formed in a similar manner. The plan on which they were made was more calculated for durability than ease to the traveller; and for our modern wheel-carriages they would be found particularly objectionable. Whatever was their entire breadth, the centre constituted the beaten track, and was made of large ill-dressed stones, laid side by side, to form a compact mass of from twelve to twenty feet broad; and therefore in their external aspect they resembled the coarse stone causeways which are still in use in the towns and highways of France. Some of the roads had double lines of this solid pavement of this nature, with a smooth brick-path for foot-passengers; and at intervals along the sides, there were elevated stones on which travellers could rest, or from which cavalry could easily mount their horses. One important feature in the construction of all the Roman roads was the bottoming of them with solid materials. Their first operation seems to have been the removal of all loose earth or soft matter which might work upwards to the surface, and then they laid courses of small stones, or broken tiles and earthenware, with a course of cement above, and upon that were placed the heavy stones for the causeway. Thus a most substantial and durable pavement was formed, the expense being defrayed from the public treasury. Various remains of Roman roads of this kind still exist in France, and also in different parts of Britain. One of the chief Roman thoroughfares, in an oblique direction across the country from London to the west of Scotland, was long known by the name of Watling Street, which has been perpetuated in the appellation of one of the streets in the metropolis.

Modern Roads.

For a description of these, and the most improved methods of construction, we beg to refer the reader to the number on CIVIL ENGINEERING. With respect to the maintenance of roads, the most advantageous plan consists in assigning the entire duty to a contractor. The trustees appointed by local acts of parliament to superintend highways, now generally employ contractors to keep the roads in repair at a specified price per mile. The cost of maintenance, interest on capital, &c., are defrayed from a tax levied at the toll-bars or turnpikes.* To say nothing of the annoyance of the system, this mode of raising the necessary funds is the most wasteful that could be contrived; on an average, 44 per cent. is absorbed in collection alone. Some years ago, Mr Pagan, a Scottish country solicitor, proposed a plan for the entire abolition of toll-bars, the consolidation of trusts, and the levying of an annual rate on horses. He demonstrated, taking the county of Fife as an example, that on his plan the roads could be maintained at little more

* Turnpikes were so called, from poles or bars, swung on a pivot, having been placed on them, and turned either way when dues were paid. Gates are now substituted for these poles in Great Britain. In Germany, the pole is still used, one end being depressed to raise the other, and so permit a free passage.

than one-half their present cost. Notwithstanding the utter indefensibleness of the existing system, it has as yet been impossible to bring the local trusts to take any steps towards realising the plan; but the subject is beginning to be again agitated, and there is some hope that a national measure may be adopted for the abatement of this nuisance.

Law of the Road.—For general convenience and safety, drivers of vehicles and riders, in travelling along a road, are expected to take a particular side; and this practice is now so well understood, and is in itself so proper, as to have become a part of the common law. The law of the road is, that when drivers meet from different directions, each shall keep his left hand to the wall or footpath. Secondly, when one driver overtakes another, and wishes to pass him, he must keep his left hand to the vehicle which he passes. In the case of either meeting or passing, each party is entitled to the half of the road. The same rules apply to riders. If these regulations be neglected, and an accident occur, the law is always in favour of the party who kept his own proper side, and no excuse can shelter the aggressor. The trustees of the road are liable in an action of damages for any injury that may be sustained through the carelessness of themselves or servants in leaving the road grossly out of repair.

According to a well-known rule, foot-passengers on pavements or side-paths are expected to walk with their right hand to the wall—that is, they keep their left hand to those whom they are meeting and passing. This custom prevents confusion in the streets of large towns, but is not a matter of law.

CANALS.

A canal is an artificial channel of water, and is usually constructed for inland navigation. Where rivers can be resorted to for purposes of this kind, they are preferable to canals, because little expense may be required to suit them for navigation, and they may be easily kept in repair. But few rivers, generally speaking, are sufficiently level, straight, or deep, to admit of being profitably navigated by barges, and therefore artificial channels require to be cut. Canals are extremely suitable in level countries possessing rivers or brooks which can afford a due supply of water. In China, from a very early age, certain large rivers have formed natural canals longitudinally through the country from west to east, while artificial canals have been made to proceed in a cross direction from north to south, thus effecting a universal water-communication throughout the empire. Canals existed in ancient Egypt in connection with the Nile, on a similar plan to what now prevails in China. Notwithstanding that canals were known to have existed from a remote antiquity in the East, it was long before they were introduced into Western Europe. In modern times, they were first used by the inhabitants of the Netherlands, in consequence of the extreme flatness of their country, and the numerous channels of water which intersect it in all directions, in connection with the lower branches of the Rhine and other rivers. In Holland and Belgium, therefore, canals in a great measure exist as an essential requisite in the general arrangements of the country, and are, in point of fact, so many ditches or drains to receive the superfluous waters.

In countries differently constituted, canals are constructed only with reference to the profit in the form of commercial speculation. The great question, accordingly, in forming the project of a canal, is, whether the anticipated amount of traffic will raise tolls sufficient to compensate the outlay of the undertaking and subsequent charges for repair and superintendence. It simplifies such an inquiry to know the following truths in reference to cost of conveyance:—The cheapest mode of conveyance is by coasting-vessels, steam-boats, &c., and these will at all times be employed for heavy and bulky goods—such as coal, barrels of liquids, iron, and other cumbrous materials proceeding coastwise. The next cheapest mode of conveyance is by barges on rivers; and the next is by means of canals. After this are ranked, in point of economy, conveyance by land on railways and roads, the last being the dearest, though often the only means of transport which can be obtained. According to this view, canals can never answer as profitable speculations when they have to compete with coasting-vessels of any description, or with any species of conveyance by rivers. They cannot even, in certain circumstances, compete successfully with railways, on account of the slowness of speed at which barges or boats are drawn along them; and as speed is becoming daily a matter of greater moment in traffic, canals are gradually losing the conveyance of every kind of goods for which quickness of transit is desirable. For the sake of economy in national resources, it is very desirable that these truths in statistics should be generally understood and remembered.

While, however, the trade on some of the lines of canal, since the introduction of railways, has sunk in an extraordinary degree, it is a remarkable fact, and one in every way worthy of notice, that in some districts where a large amount of traffic has been developed by railways, that canals in their immediate neighbourhood have suffered no loss from the powerful opposition, but, on the contrary, their trade has been increased. Thus, 'notwithstanding the enormous traffic conveyed along the London and North-Western rails, the quantity carried along the Grand Junction Canal, which meanders alongside its powerful antagonist, instead of having been drained, as might have been expected, to zero, has, from the opening of the railway in 1836 up to the present period, actually increased, as follows:—Average amount of goods annually moved on the Grand Junction Canal during the three years prior to the opening of the London and Birmingham Railway in 1836, 756,894 tons; average amount of goods annually moved during the *twelve* years subsequent to 1836, 1,039,333 tons.'

In order to meet the requirements of modern commercial traffic, in which *speed* is an essential feature, attempts have been recently made to adapt steam-power to canal traction, but with very limited success. It may not be generally known that the principal obstacle to the use of steam-engines on board canal-boats, is the injury done to the banks by the action of the water from the paddles. This obstacle has to a certain degree been overcome by the use of one-paddled boats—the paddle being placed in the line of the boat's keel; and also by the application of the Archimedean screw-propeller. Still, steam-dragging is by no means general; and canals, as a superseded idea, do not now much occupy the attention of engineers and inventors. It has also been proposed to lay rails along the towing-path, and employ steam-drags—a notion somewhat superfluous in these days, when it would be quite as economical to convert the path into a railway at once, or even to lay dry the canal, and apply its course to a similar purpose.

One of the largest canals in Europe is that which extends from the German Ocean to the river Y, at Amsterdam, by which vessels are enabled to reach that city by a direct channel, instead of sailing round by the Zuiderzee. This ship-canal was begun in 1819, and finished in 1825, at an expense of £850,000. Its length is nearly 52 English miles; its breadth 125 feet at the surface, and 38 feet at the bottom; and its depth 20 feet 9 inches. Traversing a perfectly flat country, it has no locks, except at its extremities, and is of such magnitude, that two frigates, or the largest merchant-vessels, can pass each other. There is a towing-path for horses on each side; and about eighteen hours are required to perform the voyage from Amsterdam to the ocean. As a commercial speculation, the canal yields no profit, but its service to the shipping of Amsterdam

is incalculable, and without it the town must have sunk into comparative insignificance.

France possesses about fifty different canals, some of which are of great importance for general traffic. The chief canal is allowed to be that of Briare, called also that of the Loire and Seine. It was completed in 1642, measures 34½ miles in length, and has 40 or 42 locks. The width is 25 feet at bottom. By this canal, Paris receives large supplies of inland produce. The Canal du Midi, or Languedoc Canal, makes a communication between the Mediterranean at the city of Cette and the Atlantic Ocean at the mouth of the Garonne, passing through the province of Languedoc. Altogether, there are nearly 1000 miles of canals in France.

The United States of North America possess upwards of 2500 miles of canals, the whole of which have been constructed within the last forty years. The principal undertaking of this kind is the Erie Canal, which unites the river Hudson at Albany with Lake Erie at Buffalo, a distance of 363 miles. The Miami Canal, from Cincinnati to Lake Erie, which extends 265 miles, is another great undertaking; and there are a number of other canals, scarcely less important, for the general traffic of the country. The canals of Canada are also on a great scale. The Rideau Canal, 135 miles long, connects the town of Ottawa—formerly Bytown—on the river Ottawa, with Kingston on Lake Ontario. By means of the Welland Canal, 28 miles long, connecting Lakes Erie and Ontario, and of the St Lawrence Canal, 41 miles in length, for avoiding the rapids of that river, communication is now open, for sea-going vessels, from the Atlantic to the most western ports on the Canadian lakes. In 1856, a cargo of wheat was brought from Chicago to Liverpool without transhipment.

The canals of Great Britain are believed to extend to an aggregate length of 2400 miles. The greater part are in the midland districts of England, including Lancashire, and have for their object the connection of the large seats of manufacture with the sea on both sides of the island, and with the Thames at London. The Grand Trunk Canal, connecting the Mersey with the Trent and Humber, extends 93 miles. The Birmingham and Worcester connects the Grand Trunk Canal with the Severn. The Grand Junction connects the Grand Trunk with the Thames. Thus the four great ports of the kingdom—London, Bristol, Liverpool, and Hull—are connected by canals. So generally are these and other canals spread over England, that it is supposed there is not a place south of Durham more than fifteen miles from water-communication.

Ireland has about 300 miles of canals, mostly government undertakings, and in general possessed of little trade. Scotland has a number of canals, but they are chiefly confined to the western and mid district of the country. That which possesses the largest traffic is the Forth and Clyde Canal, reaching from the Clyde, a short way above Dumbarton, to the Forth at Grangemouth. This canal, which was opened in 1790, and affords a ready communication for small vessels between the east and west coast, extends 39 miles in length; its highest level is 160 feet, with 20 locks on the eastern acclivity, and 19 on the western. The canal is connected with Glasgow by a side-cut; and it is joined by the Union Canal, which extends from near its eastern extremity to Edinburgh. The Caledonian Canal is formed in a great measure by a chain of lakes, stretching across the country from Inverness on the east to Loch Eil on the west coast, a distance of 59½ miles. The canal part is 20 feet deep, 50 feet wide at bottom, and 120 feet at top, which affords a passage to frigates of 32 guns, or merchant-vessels of a similar size. This great canal was undertaken as a public work by government; and after a labour of eighteen years, was opened in 1822. It possesses 13 locks on the east, and 12 locks on the west declivity, the highest level being 94 feet. By this canal, the dangers of rounding the northern extremity of the island by the Pentland Firth may be avoided; but, from the prejudices of seamen, it has never been much used. As a means of allowing steam-boats to run between the Clyde and Inverness, the canal has been of considerable public service. The expenditure for construction, repairs, and maintenance, up to 1855, was £1,361,704; of which £1,242,367 had been derived from public grants, and only £85,614 from canal dues.

Two great undertakings, which invite the concurrence of all commercial nations, have been projected and discussed for years: a canal, namely, across the Isthmus of Panama, to unite the Atlantic with the Pacific; and another from the Red Sea to the Mediterranean, over the Isthmus of Suez. Neither undertaking has yet got further than surveys and estimates.

RAILWAYS.

Before the practice of steam-navigation had attained that degree of improvement which it now possesses, a not less wonderful mode of travelling by steam-power on land had come into use; so that during the first thirty years of the nineteenth century, infinitely greater improvements in the means of locomotion have been discovered and brought into practical operation for the benefit of mankind, than had ever previously been known. To understand and value the application of steam-power to land-travelling, we must advert to the subject of draught on common roads.

There exist three obstacles to the rapid motion of carriages—terrestrial attraction, the atmosphere, and friction. By no human power can the first two be removed, but the latter can be so far modified as to form little or no opposition. On common roads, the friction is generally so great as to absorb a large percentage of the force expended in drawing the carriage. To reduce this, tramways or continuous parallel lines of smooth stone are sometimes laid down on steep roads; but the use made of them by careless drivers does not compensate for the expense of their construction.

The draught of a horse upon a macadamised road may be set down at a ton, and the highest rate of speed at which horses can go, when dragging a weight, at ten miles an hour. These data shew how far horse-power is from being fully available for the great purposes of commerce. Two hundred horses were necessary to perform the journey of the mail from Edinburgh to London, a distance of 400 miles—the time expended being forty-three hours, and relays of four horses being required at every eight miles. This rate of locomotion being attained, by improvements on roads, carriages, and in the breed of horses, nothing more could be done. Something new required to be devised.

The idea of employing steam-power to drag carriages over common roads, and thus save a large outlay for horses, besides accomplishing a greater speed, was suggested by various enterprising minds, but to its practical application there were, and are, many serious objections. Independently of the ordinary and unavoidable roughness of common roads, all highways are less or more uneven; because to construct them upon a perfect level throughout, would be attended with an expense which the tolls from any traffic could not sustain. The general unevenness of roads, therefore, causes a great loss of drawing-power. In these circumstances, it is evident that, for the avoidance of friction and economising of forces, an entirely new species of road required to be contrived. This important desideratum is found in the invention of *railways*. The design of a railway is to furnish a hard, smooth, and unchanging surface for wheels to roll upon. No provision, as respects smoothness, is required for any part of the path, except the narrow lines which are immediately to come under the rim of the wheels.

The earliest railway of which there is any account was one constructed near Newcastle-upon-Tyne. In Roger North's *Life of Lord Keeper North*, he says that at this

place, in 1676, the coals were conveyed from the mines to the banks of the river 'by laying rails of timber exactly straight and parallel; and bulky carts were made, with four rollers fitting those rails, whereby the carriage was made so easy, that one horse could draw four or five chaldrons of coal.' One hundred years afterwards, about 1776, Mr Curr constructed an iron railway at the Sheffield colliery. The rails were supported by wooden sleepers, to which they were nailed. In 1797, Mr Barns adopted stone supports in a railway leading from the Lawson main colliery to the Tyne, near Newcastle; and in 1800, Mr Outram made use of them in a railway at Little Eaton, in Derbyshire. Twenty-five years afterwards, this species of road was successfully adopted on a public thoroughfare for the transportation of merchandise and passengers—namely, the Stockton and Darlington Railway, which was completed in 1825, and was the first on which this experiment was made with success. From that time, accordingly, a new and wondrous era commenced in the history of inland conveyance.

It is a remarkable circumstance, that the early practisers of railway transport could not imagine that a carriage, moved by steam-power, could proceed along the rails without the aid of toothed wheels and a rack; and to overcome this imaginary difficulty, no small degree of expense and labour was fruitlessly incurred. About the year 1815, Mr Blackett of Wylam, near Newcastle, effectually proved, by repeated experiments, that the adhesive power of the wheels on the rails was at all times sufficient to cause a progressive motion in an engine, with a train of loaded carriages, upon a railway either level or with a small acclivity. Important as was this discovery, fifteen years elapsed before steam-locomotives were fairly established. This great triumph of art occurred in connection with the opening of the Liverpool and Manchester Railway on the 15th of September 1830, since which period railways have spread to all populous parts of the country.

Simple as is the idea of a railway, a prodigious expense is necessarily incurred in bringing it into practical operation. In addition to the cost of construction, the purchase of the land over which the railway runs, and the preliminary expenses of obtaining a parliamentary act, amount often to vast sums. The parliamentary expenses alone are not seldom as much as £2000 per mile. The cost of railway construction, however, with all the recent improvements, is now much less than formerly, and may be set down as from £16,000 to £30,000 a mile. The Belgian railways cost £12,600 per mile, on an average. In America, where the lines are mostly single, the average cost has been £6866, and would have been much less but for the protective duties imposed on foreign rails. In Scotland, single lines have been lately constructed at little more than £4000 per mile.

For explanation of the various points connected with the construction of railways, we refer the reader to the number on CIVIL ENGINEERING; and proceed at once to give some notices respecting their management and their commercial features.

At the period of the opening of the Liverpool and Manchester Railway—the first on which steam-locomotion was tried on a large scale—no one, even of their most sanguine supporters, seemed to entertain the slightest notion of the immense importance which railways would assume among the commercial interests of the nation, and as aiding our great industrial operations. The amount of money already sunk in the construction of railways in the United Kingdom seems almost fabulous. Only twenty-six years have elapsed since the system was successfully inaugurated; but in that brief space—how brief in the history of a nation!—8000 miles of railway have been opened, and in their construction have been spent upwards of £300,000,000 sterling! If we further take into account the mileage opened in our various colonies, we may form some idea of the commercial importance of the railway system of the empire. But not only from this point of view must the subject be considered—we must remember the large amount of money circulated by the employment of so many people engaged in the working and maintenance of the lines, and the manufacture of the various materials and machines connected therewith. While, however, it is gratifying to see this evidence of the wealth of our country, which in so short a time could bear so large a drain upon its resources without materially interfering with the usual operations of commerce, it is but right to state that their commercial success, as paying or lucrative concerns, has not been commensurate with the expectations of their projectors. Thus Mr Chattaway (*Railways, their Capital and Dividends*. Weale, London) estimates that there are 'in the United Kingdom twenty-eight railways which yield no return upon their ordinary share-capital; in other words, upwards of £22,000,000 of the capital invested in these important undertakings is utterly unproductive.' And of the paying lines, the experience of the last five years—'five years,' as the same authority remarks, 'of almost unexampled commercial prosperity'—shewed an average of three shillings per cent. of a dividend per annum.

To enter fully into the causes of this would take up more space than we can allow, although the subject is one of importance, as furnishing useful lessons for enabling parties to judge of the probable success of future undertakings. We must therefore content ourselves with a very brief glance at the chief points involved. Of the capital expended in connection with the railway system during the last twenty-six years, there is a large amount, none of which was actually spent in furtherance of the main object—the *construction* of the railway, from the traffic of which the dividends were to be obtained. Many of the schemes were brought forward at a time when a mania for speculation infected nearly all classes. Under this influence, sums of money, seemingly inexhaustible, were thrown without restriction into the hands of the promoters of the schemes; and these sums they recklessly squandered in a multitude of ways, few of which had a direct bearing on the purpose intended, and which were summed up in the convenient phrase, 'preliminary expenses.' And in the instances where construction was set about, the same lavish expenditure characterised all the proceedings; engineers, surveyors, draughtsmen, and engravers were engaged at most extravagant rates. In this way immense sums were needlessly thrown away. And to this must be added the unnecessary and lavish expenditure on the works themselves. Need we instance the money sunk in buildings of elaborate architecture and immense extent, and these often at insignificant stations; double lines laid down where single ones would have sufficed; expensive materials and structures adopted where the simplest would have served the purpose; and all the details of construction carried out with the same minuteness and finish, as if the engineer had been experimenting to discover the most expensive mode of operation, or as if he had been making a model for a museum! It is well known that many expensive and elaborate engineering works might have been avoided; and it is even said that some engineers were more solicitous to carry out operations in which their skill would be displayed, than anxious to secure the commercial success of the line.

Another fruitful source of loss was the practice of what is called *guaranteeing*. The formation of a multitude of branch-lines, connecting the neighbouring towns and villages with the main-line, was encouraged by the directors of the latter guaranteeing a certain rate of dividend on the capital of the branch. This was done with a view to prevent the traffic of these places being diverted into rival lines, in *esse* or *posse*, and to have the branches as feeders to the main-line. These advantages were in nearly every case illusory; scarcely a branch-

line has been found to pay its own working expenses; and many of the lines to which 8, 9, and even 10 per cent. was guaranteed, brought in *nil*, while some paid only 1 and 2 per cent. 'Of all the causes which,' says Mr Chattaway, 'have tended to depreciate the value of railway property, none have had a more prejudicial effect than the system which has obtained of recklessly guaranteeing other undertakings, and of constructing branches through districts possessing no remunerative traffic. Trunk-lines containing within themselves all the elements of prosperity, have thus been brought to the verge of bankruptcy.'

But while railway companies have of themselves been guilty of great extravagance, they have been also the victims of two systems, which have forced them into large expenditure: we refer to the parliamentary expenses, and the system adopted by landowners and holders of property, of asking monstrous sums for plots of land or houses through which the railway was designed to pass, and of throwing every obstacle in the way of the promoters, and driving them into expensive litigation. It is impossible to estimate the loss sustained from these two causes alone: for parliamentary expenses, it is calculated that no less a sum than £14,000,000 has been required. The parliamentary expenses of some railways are almost incredible; the Blackwall Railway, for instance, spent in this way nearly £15,000 a mile. Half a million has been spent in obtaining a railway act; while on another railway the solicitor's bill amounted to nearly a quarter of a million. On an average, it may be computed that the parliamentary expenses of existing railways have exceeded £1000 per mile. The mere statement is enough to excite indignation, when we consider that every railway is calculated to promote the welfare of the district through which it passes, and in consequence, should meet with the fostering care of the legislature, rather than with the hinderances and outlay which its way of proceeding involves. In the opinion of good authorities, the whole of our railway laws could be put upon a very simple and efficient basis at little expenditure. It is to be regretted that all our enactments have been characterised by a vacillating, uncertain policy; so much so, that this cause alone has been reckoned 'as one of the principal causes' of the depressed condition of railway property. As to the other cause of unnecessary expenditure forced upon railway companies, the numerous instances of rapacity and unscrupulous dealing on the part of holders of land, &c., redound little to their credit. In almost every case the company has been considered a fair object of plunder; and to get the most out of it, without regard to the principles of honesty and fair-dealing, seemed to be the object of nearly every proprietor who had property to dispose of. Thus, land worth £5000, has been sold to a company for £120,000; £50,000 has been asked in the first instance, and less than £1000 accepted, but this, after litigation. The opposition of landowners to lines passing through their estates has been bought off at an expenditure of £50,000, £60,000, and £120,000; and what renders these instances all the more disgraceful, the opposition has been simulated. The dealings of the British public in this matter, as well as in the still more celebrated line of railway speculation, form a dark chapter in the commercial history of the people. The lessons to be learned from the history of these errors, and worse than errors, are obvious, and it is to be hoped the public will profit by them in the future. As regards the probable paying capabilities of any projected line, Mr Chattaway says that it may be laid down as an axiom, that if it costs £30,000 a mile, or even approximates to this, 'the old standard,' the receipts will not pay for the outlay; but if, on the other hand, the cost is 'limited to £10,000 or £12,000 a mile,' the line will 'indubitably afford a good return to its shareholders, however thinly populated and unpromising may be the district through which it runs.' With reference to the commercial improvement of railways constructed on the old system of lavish expenditure, the same excellent authority has the following suggestive remarks: 'Inventive genius and mechanical skill, which are constantly economising the cost of production of all the staple articles of manufacture in this country, will yet accomplish much for railways. Improvements in the construction of permanent way and rolling stock; expedients for lessening the immense wear and tear, which are the result of carrying heavy loads at high velocities; improved means of generating and applying steam-power; and possibly the substitution, ultimately, of some more economical, but equally powerful agent—all will tend to lessen the heavy working charges which now press so severely upon railway resources. Further than this, we may reasonably expect, that by the aid of accumulated experience, railway working will become virtually a science; that greater immunity from accident will be obtained, consequent upon more perfect arrangement; and that by placing at the head of departments men of known ability and enlarged views—men who possess the art of conducting, in the readiest manner and to the greatest advantage, the vast amount of traffic which railways have developed—these important undertakings will eventually be raised from their present state of depression.'

There is perhaps no point connected with the railway system possessing more interest than that of the amount of traffic *created* by it. Previous to the opening of the Liverpool and Manchester Railway, estimates were made of the probable amount of traffic in passengers and goods: these are in strange contrast to the results of experience. Thus, it was estimated that 250 people would be the average daily number of travellers. The traffic of 1845 shewed a result of six times the number. Railways have not failed as commercial speculations in consequence—as some have asserted—of actual traffic being far below the estimated; on the contrary, the traffic, in nearly every line opened, has progressively improved from year to year; and this result is noticeable even when comparing the traffic of bad or commercially depressed years with that of good ones. Thus, in 1844—a year of great commercial prosperity—the number of passengers travelling on the London and North-western amounted to 1,896,068, and the total receipts from all sources £1,493,226—the number of miles run over being 82,522,861, in passenger-trains only; while in 1848—a year of great commercial and general depression—the number of passengers was 5,999,347, the total receipts, £2,194,092, and the number of miles run over, 195,129,791. In the half-year ending December 1849, the number of passengers conveyed on all the railways of the United Kingdom was 35,073,672; for the half-year ending December 1850, 41,087,919; and for the half-year ending December 1851, 47,509,392. In 1854, the total number conveyed was 111,206,707—of which England and Wales had 92,346,149; Scotland, 11,949,388; and Ireland, 6,911,170: the number of miles travelled over in England being 1,379,249,238; in Scotland, 146,244,120; and in Ireland, 96,555,135. In England, in the same year, the number of passengers in each train averaged 85; and the average distance travelled over by each passenger, 15 miles; the average sum received from each being 25·05d. In Scotland, these averages were—94; 12·2; and 15·20d.: and in Ireland, 81·4; 14; 18·12d. In England, the revenue from passengers amounted to £7,896,502; from goods, £8,567,264; and for mails, horses, and carriages, £879,257. In Scotland, the passengers produced £756,870; the goods, £1,147,656; and the mails, &c., £93,791. In Ireland, £521,637 were realised from passengers, £255,847 from goods, and £96,956 from mails, &c. The gross revenue of the railways of the United Kingdom is nearly twenty millions and a quarter, the average daily number of passengers 304,676, and the daily receipts £55,386.

That the passenger traffic is capable of still further extension, at least among the middle and lower classes, is evident. We believe that the paying capabilities of cheap excursion-trains are little understood by railway companies, and that erelong a great development of this branch will be witnessed, when once they bring their energies to bear upon the question. Ample evidence of the existence of a large mass of the population, who will only travel when induced by the temptation of low fares, is met with in the experience of the railway companies in the manufacturing districts of England. Nor do the advantages resulting from low fares rest here; we believe that a due revision of the traffic department of all railways, with a view to the adoption of a lower tariff of rates, would be beneficial in developing a large amount of *business* traffic. As it is, a large percentage of the steam-power is expended in dragging empty carriages; trains rarely carry more than half their load. By proper management, this will in time be avoided, or greatly obviated. It is impossible to overrate the importance of endeavouring to establish a lower rate of charges than at present obtains. 'Cheapness of fare,' says the Report of the Committee of the House of Commons, 'may create a traffic which otherwise could not possibly exist.' If a traffic of 20,000 tons requires a charge of 10½d. a mile to make it remunerative, a traffic of 1,000,000 tons would be remunerative at about a *halfpenny per mile*.

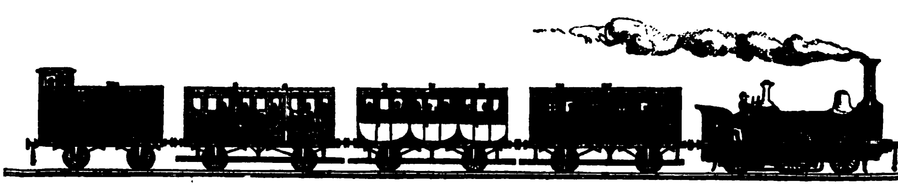
The railway system now extends more or less over all Europe, and is even penetrating into Asia and Africa. It was calculated by Dr Lardner, that in 1850 the gross receipts of the European railways amounted to £23,309,000, of which £12,755,000, or about the half, was collected on the railways of the United Kingdom. The receipts in the United Kingdom are since then nearly doubled; and we may assume that in the rest of Europe the increase of railway locomotion has been still greater. In America, railways are undergoing an extraordinary development. In 1848, the number of miles was 6000, and in 1853, it was 14,508. Massachusetts alone, with a population about one-third that of Scotland, had 1200 miles of railway. The existing railways in 1856 are stated at 20,000 miles; and it is anticipated that before 1860 they will exceed 35,000 miles. Both the construction and management of American railways are on a more simple and economic scale than in Europe.

In considering the immense number of passengers that travel yearly on our railways, another point of interest is opened up to us—namely, the amount or percentage of accidents happening in consequence. Statistics on this point prove very conclusively that railway travelling is much safer than stage-coach travelling. Although an accident by railway is terrible in its results, as compared with that of a stage-coach, we must remember that accidents less frequently happen, and that the number of passengers travelling at the same time is much greater in the former than in the latter. The chances of being killed are one in every half-million nearly; and of being injured, one in 120,000. Thus, for the year ending December 1851, 47,509,302 passengers travelled in the United Kingdom, out of which 113 were killed, and 264 injured—of whom 9 were killed, and 14 injured owing to their want of caution, or their own misconduct. But out of 113 killed, only 17 were passengers, the remainder being servants of the companies or contractors. A novel species of insurance, and one to which the railway system has given rise, is the 'Railway Passengers' Insurance.' The following is given by Mr Williams as the principle upon which the company is established: 'If every traveller, during the second six months of 1851 had paid a penny for every journey, into a relief-fund, the amount realised would have been £197,955. This would have permitted the payment of £1000 to the representatives of each person killed, and of £250 to each person injured. Each railway traveller pays, on an average, about 1s. 8d. each journey; so that an additional penny would have secured for these poor sufferers the most incalculable relief.' The company has made arrangements by which insurance-tickets can be had at nearly every station in the kingdom at the following rates: Threepence to insure £1000 in case of death, for first-class passengers; twopence for £500 for second, and one penny for £200 for third-class passengers, with compensation in case of injury. Only a small percentage of railway passengers avail themselves of this excellent provision; according to the experience of the company in 1851, but one in every 183.

Considering the immense number of passengers that travel by railway, and the almost incredible number of miles run over by them, it is gratifying to witness the small percentage of accidents. It has been the fashion to blame railway companies for their carelessness, and their indifference to the value of life; but a close investigation will prove that really the pains they take to prevent accidents is very great. The various contrivances and plans adopted to insure this, it is now our duty to notice.

Signals.—The signals employed at stations, though apparently complicated, are in reality very simple. Red always denotes 'danger,' and conveys an injunction to the guard to 'stop' the train; green, 'caution,' or to drive slowly; white, or no signal, means 'all right.' Coloured boards, elevated on posts, are generally used for day-signals. The signal is shewn by turning the board across the line of the rails; when no signal is meant to be shewn, the edge of the board is turned towards the driver. Instead of coloured boards, a movable arm is sometimes attached to the mast; raised at right angles, it signifies 'danger;' sloping at 45°, it signifies 'caution.' When dark, a lamp, elevated on the signal-post, is made to shew a white, green, or red light, by means of movable glass slides. The boards and slides are moved by wires, the signal-posts being generally at some distance from the station. Sometimes there are two sets of signal-posts, main and auxiliary. Flags and hand-lamps are also used for particular purposes. In long tunnels, the electric telegraph is used to communicate with the policeman at either end. In thick foggy weather, the various ordinary signals are rendered useless, and fog-signals are put in requisition: these are composed of a detonating mixture placed between disks of metal, the whole being clasped to the rail. The disks lying on the upper side are crushed by the engine-wheels passing over them, and a loud report is heard, which acts as a danger-signal.

Carriages.—The distinction between the different



classes of carriages used, and their fittings, is so well known, that we need not take up space by any description; suffice it to say, that in no department has there been so little progressive improvement shewn

as in that of carriages. The cut represents a train composed of locomotive, first, second, and third class carriages, and a luggage-van, containing the guard's box. The locomotive is usually followed by a separate carriage, called a *tender*, carrying a supply of fuel and a cistern of water; in the form of locomotive here represented, which is adapted for short distances, the supplies are carried in a compartment on the locomotive behind the driver.

To lessen the amount of concussion between the carriages, each is provided at back and front with *buffers* —that is, cushioned steel rods acting upon springs which are made capable of resisting a high degree of pressure. To prevent oscillation during high rates of speed, none of the plans proposed are, we believe, so efficient as well-balanced and well-constructed wheels and carriages. Accidents frequently happen from the insecurity of the *couplings;* to remedy which, various contrivances have been tried. In Mr Chattaway's patent buffing and coupling apparatus, the buffer and draw-hook are combined and placed in the centre of the carriage, instead of having the buffers at the corners, as is usually the case. A portion of the rod is screwed, and fitted with an adjusting apparatus, by which the coupling may be disengaged or tightened up as desired. 'By this method, separate corner-buffers and side-chains are dispensed with, the buffing, drawing, and coupling apparatus being all combined on one central rod.' Central buffing, according to good authorities, is in every way preferable to the present system of having corner-buffers. In connection with the safe working of railways, the *brake* or *break* is of first importance; and on this contrivance a large amount of mechanical ingenuity has been brought to bear. The break consists of a set of wooden blocks, which are made to press against the wheels by means of a system of levers. In general, the break only influences the particular carriage on which it is fixed; but in Mr Newall's, which we are about to describe, and which is now accepted as a reliable and efficient appliance by railway authorities, the guard is enabled to work simultaneously all the breaks in the train. The connection between the breaks throughout the train is made by carrying tubular shafting over or under the carriages; and this is fitted up so as to accommodate itself to the varying movements of the train. Through this shafting, both the engine-driver and the guard are enabled to work all the breaks. At one end of the break-van or carriage, there is a hollow cylinder, four feet in length and four inches in diameter, which is fixed perpendicularly against the carriage. A spiral steel spring works in this cylinder, and actuates a cross-piece, whose movement is communicated directly to the lever of the break. The expansion of the spring forces down the cross-piece and applies the break. To release it, the cross-piece has attached to it a rack, which the guard raises by turning a hand-wheel and pinion. This compresses the spring; and to retain it in this position till the break is again required, a catch is applied to the pinion. In other forms of break, there is no spring; but the end of a vertical screw, which is turned by a hand-wheel, acts directly on the lever-system that applies or withdraws the wooden blocks.

It is of great importance that the guard and the engine-driver should be able at any instant to communicate with each other. The simplest plan yet introduced, for effecting this object, is the following, which has been recommended by the Railway Clearing-house (see page 430)—it is right, however, to state that there is by no means a uniformity of opinion as to its efficiency. A single strike-bell is affixed to the engine-tender, as near as possible to the place usually occupied by the driver. A strong cord actuates this, which is carried along the sides of the carriages to the guard's van, and is there wound round a wheel, to which a balance-weight is attached, to keep the cord tight—allowance of course is made for the variation in the length of the train. The bell is struck by the guard turning the wheel rapidly.

For the security of railway conveyance, a primary point is the keeping of the permanent way in perfect order. The arrangements for this are very complete, and are most rigidly followed out. 'Overlookers' are appointed to each section of the line; under these officials are foremen, whose duty it is to examine with care every morning each portion of the rails, chairs, and sleepers. Should repairs be required, precautions are taken to signal the trains, and workmen are summoned according to the exigency of the case. When the repair is of some extent, as in the relaying of a portion of the rails of the line, instructions are forwarded to the engine-drivers and the workmen employed, so that little interference with the working of the trains and the relaying may result.

When the railway passes on a level with an ordinary road, special means are taken to prevent accidents. A policeman is in constant attendance at the spot, whose duty it is to stop the ordinary road-traffic by closing the gates, at each side of the railway, before the time a train is expected to pass. When the road is opened for traffic, the gates are placed across the line of rails.

Locomotives.—Locomotives are now made of greater power and weight than at first, requiring a corresponding increase in the strength of the rails. Instead of the original locomotive of four or five tons, costing some £500 or £600, we now have them traversing our railways of twenty to forty tons-weight, involving an outlay of £2000 or £3000. The power exerted by some of the first-class engines is enormous: on the broad gauge, express engines have been introduced equal to the dragging-power of 700 or 800 horses, and capable of hurrying trains along at the rate of 60 miles an hour; the consumption of coke being 20 pounds per mile, and the pressure of steam 120 pounds to the inch. Engines of equal or greater power are in use on the narrow-gauge lines—one on Crompton's patent, exerts a power equal to 1140 horses. Originally, locomotives were supported on four wheels; they are now constructed generally with six, and sometimes eight—the diameter of the driving-wheels varying from six to eight feet. For a description of the locomotive, its arrangement and construction, we refer the reader to the article on the STEAM-ENGINE.

The following account of one of the ordinary engines for passenger traffic on the Great Western Railway may be interesting. It is capable of taking a passenger-train, of 120 tons-weight, at an average speed of 60 miles an hour. The power is equal to 1000 horses theoretically, but of 743 when tested by the dynamometer. Its weight, with coke and water, is 35 tons; the empty tender weighs 9 tons, and it usually carries 30 hundredweights of coke and 7 tons of water. There are 305 tubes in the boiler, giving a heating surface of 1759 feet, and the fire-box gives 150 additional. The diameter of cylinder is 18 inches, length of stroke, 2 feet, diameter of driving-wheel, 8 feet. The actual consumption of fuel with a load of 90 tons, and an average speed of 29 miles, is 20·8 pounds of coke per mile. The maximum steam-pressure is 120 pounds to the square inch. In the express locomotive in use on the (narrow gauge) London and North-western Railway, the diameter of cylinder is 18 inches, length of stroke, 24 inches, driving-wheel, 8 feet. The amount of heating-surface in the tubes is 2136 feet; in the fire-box, 154; the evaporation equal to 1140 horse-power, the pressure of steam, 120. With reference to the mode of estimating the power of a locomotive, a good authority has the following: 'The high pressure which yields power, and the rapid evaporation which gives the means of applying the power directly to obtain speed, are dependent upon the effect with which heat can be applied to the water in the boiler; and hence the amount of surface exposed by a boiler in any manner to the action of the fire in the furnace or fire-box, or to heat arising from it; that is to say, whether by means of

tubes running through the boiler, and forming flues to the heat from the fire, or by a casing about the fire in the furnace, is the measure of the capability of the engine in respect both of power and speed.' The evaporation of a cubic foot of water per hour is equal, in the ordinary method of calculation, to one horse-power; this being effected by the consumption of from eight to ten pounds of coke. On some branch-lines, a light species of locomotive, with passenger-carriage attached, the whole forming one structure, has been introduced; that constructed by Mr Samuel weighed only twenty-five hundredweights, and conveyed seven passengers at the rate of thirty miles an hour.

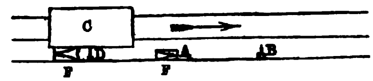
A locomotive is calculated to be capable of running 95,000 miles before requiring repair. The average distance run annually by a locomotive is 30,000, and the deterioration in value is estimated at three-halfpence for each mile run.

In America and Belgium, most lines consist of but one track; British railways, with few exceptions, possess two tracks, suitable for trains going in opposite directions; besides which, there are turn-offs or sidings, at which quick-going trains may pass those of slower motion. At certain convenient points along the line there are station-houses, at which the trains stop to take up and set down passengers, and there is no stoppage at any other place.

The termini of the principal railways are most gigantic concerns, and are complete, not only as regards their facilities for the transmission of passengers and parcels, but for heavy goods. At the Camden station of the London and North-western Company, there are twelve miles of rails laid down in an endless variety of directions. On most of the lines there are slow trains, taking goods and second-class, or an inferior kind of carriages; and fast trains, taking only first and second class carriages; some lines also have mail-trains, which proceed at more than usual speed, and taking only first-class carriages, stop at fewer places by the way.

The usual speed of an ordinary railway-train is from twenty to twenty-five miles an hour, though sometimes it is much more. The mail-train from London to Manchester (188½ miles) usually takes six hours, being at the rate of thirty-one miles; the express from London to Edinburgh by the Great Northern (399½ miles) performs the journey in eleven hours. The speed on continental railways is less than in Britain; in Belgium, for instance, the average speed is 20 miles. High velocities are much more injurious to the permanent way as well as to the engine, than moderate rates of speed. Another point of interest to be noted, is the decrease of tractive power with increase of speed. Thus, an engine proceeding at the rate of 10 miles an hour, may drag 250 tons; while only 28 can be drawn by the same engine if the speed is increased to 30 miles.

The arrangement for carrying on the mail-contract on the chief lines is worthy of notice here. The post-office van is a carriage consisting of two small apartments, one of which is appropriated to the guard, whose duty is to exchange the bags, and the other is fitted up with a table for sorting letters, and holes round the walls for their reception. The manner in which the duties of the clerk and guard are performed in this flying post-office, is strikingly significant of the new order of things introduced by the railway system. Outside the vehicle, a species of net is extended by a hoop, and into this the letter-bags are dropped as the train sweeps onward in its course—the bags which are to be left being at the same time tossed from the window by the guard. The fresh bag of letters being received, is speedily opened, its contents rearranged, and a new bag for next town being made up, is ejected as before at the place of its destination. Self-acting apparatus has been introduced on many of the principal lines, by which the bags are taken up and delivered at the stations without involving either manual labour or the stoppage of the train. 'This apparatus consists of a wooden frame and net attached, shewn in plan A, and an iron



post, B, fixed in the ground at the side of the railway, in a direct line with each other; and a corresponding apparatus affixed to the side of the carriage, C—namely, a projecting arm, D, to support and deliver an envelope with bag or parcels enclosed, into the net, A, which is fitted with conveying guide-lines, F, to receive them. These lines are of great importance, the acute angle being the part in which the envelope is griped.' A folding-net is attached to the side of the carriage, to receive the envelope from the delivery-standard, B.

There are certain advantages in the arrangements of all the railways over common roads, which deserve to be mentioned. Each line, being the property of a private association, is secluded from one end to the other from the intrusion of the public; and therefore no jostling or confusion need take place, either upon entering or leaving the carriages. The rails of one line likewise join those of another, by which means carriages generally proceed onwards, without changing passengers or luggage. A carriage in which passengers take their seats at London can go straight on to Edinburgh or Aberdeen. The extraordinary magnitude of the railway undertakings, has enabled the directors to organise rules which could never be enforced in the irregular scramble of stage-coaching. It is customary to dress the subordinate functionaries on all the lines in a distinctive uniform—each man having his number inscribed in figures on some part of his dress; so that if any one be guilty of incivility or inattention, he can be easily reported to his superiors. There is one pleasing peculiarity in the arrangements which is entitled to the highest commendation: it is the rule that no officer shall, on any account, take a fee from passengers, on pain of instant dismissal. Those who imagine that fees to guards, coachmen, or waiters, are requisite to insure civility, will be surprised to find that railway attendants are infinitely more polite and attentive than their brethren of the coach-conveyances. This in itself gives travelling by railway a great superiority over all other modes of public conveyance. On all the lines, there are waiting-rooms, both for ladies and gentlemen, at the different stations; and at all the important ones, there are refreshment-rooms, where meals stand ready prepared for the passengers.

The arrangements necessitated by the plan, now so general, of booking passengers through from one town to another, passing over different railways, are of a somewhat complicated nature, and deserve notice here. This business is managed by the officials of what is termed the Railway Clearing-house. The committee of management consists of delegates, one from each of the railway companies. The duty of the officials under this committee is to make up from time to time balance-sheets, shewing the state of accounts between the companies working in conjunction. The proceeds are divided among the companies, in proportion to the mileage contributed by each to the common traffic. The rate of payment is generally a matter of arrangement specially entered into between the companies. The data from which the accounts are made up are obtained by what are called 'number-men,' whose duty it is to attend at the junctions, and carefully note the number of the engines, wagons, carriages, &c., passing from one line to another. The number of passengers is also ascertained by the clerks at the various clearing-house stations taking a note of the tickets issued and received; the goods-traffic is ascertained in the same way. Nearly all the important narrow-gauge lines are connected with the Clearing-house, each contributing to its working expenses in

proportion to the amount of the balance which is paid to its credit. Such a system has been productive of great benefit to the public, not only in point of convenience, but from its tendency to equalise and lower the rates of transmission. The principle is, however, capable of much extension, and will erelong, in all probability, be arranged so as to comprehend within its jurisdiction all the railways in the kingdom. It carries on its operations under the protection of a special act.

It only remains for us to notice the *personnel* and the working-stock of a first-class railway company; and to glance at the proportion which the working expenses bear to the general receipts. The following will give an idea of the employment afforded by the London and North-western Railway Company:—2 secretaries; 1 general manager; 3 superintendents; 2 resident engineers; 966 clerks; 3054 porters; 701 police-constables; 738 engine and fire men; 3347 artificers; 1452 labourers—total employed, 10,266. In the collection and delivery of goods and parcels, 253 vans are employed; and in the working of the line, changing carriages at sidings, &c., 612 horses. The extent of Messrs Pickford's establishment for conducting the goods-traffic of the same railway will be seen from the following:—The number of clerks, 234; porters, 438; horses, 396; vans, 82; wagons, 57; drays, 25. The working-stock of the same railway in 1851 was as follows:—Locomotives of all classes, 582; first-class carriages, 586; second do., 564; third, 344; post-office vans, 25; 271 horse-boxes; 249 carriage-trucks; and of guards, break, and parcel vans, 210. The goods-traffic stock consisted of 8195 wagons, 232 sheep-vans. The cost of a locomotive may be taken at £2000; of a first-class carriage, £300 to £350; a second do., £200 to £260; third, £200; horse-boxes, £120 to £150; goods-wagons, £100 to £120; luggage-vans and breaks, £70 to £100; coal-wagons, £60 to £80; sheep and cattle wagons, £100. In regard to the working expenses of railways, we extract the following from a series of useful tables on the subject, embracing all the important railways in the kingdom, given by Mr Chattaway:—For the half-year ending November 1851, it appears that the total expenses were £641,003; and the total receipts from all sources, £1,409,128; the percentage of expenses to receipts being 45·489. The amount expended in maintaining the permanent ways was upwards of £78,000, the percentage to receipts being about 5½; the locomotive expenses upwards of £191,000, the percentage, 13½; for carriage, &c., repairs, £54,000 was spent, being nearly 4 per cent. on the receipts. The charges for the merchandise traffic were nearly £150,000, the percentage to receipts being nearly 10½. The coaching-traffic charges were nearly £93,000, the percentage, 6½. The general charges were £23,482, being more than 1½ per cent. on the receipts. The total working charges were nearly £590,000, making the percentage of expenses to receipts 41·641. To this was added the rates, taxes, and the duty paid to government on passengers—a tax of which the general public is not aware—amounting to £54,221, being nearly 4 per cent. on the receipts.

It is mainly to the reduction of the working expenses of the various railways that the shareholders must look for an increase of dividend. To do this effectually, and yet without compromising the safety of travellers, by impairing the efficiency of the permanent way and the rolling-stock, requires the exercise of great judgment and prudence. It is indeed in this department that railway management is at once tested.

In concluding our remarks on railways, we might enlarge upon the social and political benefits conferred on the community by their general introduction; but tempting as the theme is, we must refrain, contenting ourselves with the following extract, which, in few words, contains a summary of the advantages derived from them socially, politically, and commercially. 'Increased government revenue—increased value of all property—increased cultivation and produce, and extension of manufactures—increased accommodation to all classes for intercommunication—diminished cost of all descriptions of goods to consumers, and increased consumption by accession of numbers—diminished risks of war and insurrection, with increased powers for their suppression—a measure of universal benefit, without a drawback or objection, if selected and carried out under due provisions, with judgment and discretion.' The reader anxious to go more fully into the details of the railway system may consult the following works with advantage:—*Railways, their Capital and Dividends*, by E. D. Chattaway (Weale); *Railways, and Sketches of the Construction and Material*, by R. M. Stephenson (Weale); *Our Iron Roads*, by F. S. Williams (Cooke); and Dr Lardner's *Railway Economy*.

Atmospheric Railways.

If a smooth and straight metal tube be provided at one end with an air-tight piston, and the contained air be extracted at the other end, the piston, on being let go, will traverse the tube from end to end, being, as it were, forcibly driven by some unseen agency. This agency is the weight or pressure of the atmosphere, which, acting upon the piston, drives it along with a force proportionate to the vacuum formed in the tube and the number of square inches of the piston's surface. This, then, is the principle of the atmospheric railway.

If the reader will suppose the tube large enough to admit a train of carriages, the train being attached to the piston, he will have a good idea of the atmospheric railway, as first proposed to be established between London and Brighton. This mode of travelling in a continuous tunnel not possessing many charms to ordinary travellers, excepting that of novelty, the scheme, as might be supposed, did not succeed; but the idea being a good one, many engineers and men of science directed their attention to the subject. The first evident improvement to be made was to have the carriages *external*, and connected with the piston by some contrivance sliding along a slit or opening made in the upper side of the tube. Messrs Clegg and Samuda patented improvements, which were first tried experimentally at Wormwood Scrubbs, on a portion of the West London Railway; and these proving successful, were adopted by the Dublin and Kingstown Railway on that part of their line between Kingstown and Dalkey, a distance of about one mile and three-quarters. This line is much inclined; the carriages descend by their own gravity, and are propelled up the incline by the atmospheric agency. This first application of the atmospheric principle is still in successful operation. It was subsequently tried by the London and Brighton and South Devon companies; but difficulties in the working ultimately induced the directors to abandon the principle, and adopt the usual system. Although many of our first engineers expressed their confidence in the atmospheric principle, nevertheless it has failed in establishing itself as an economical mode of locomotion. Its 'weak point' is doubtless the valve, and the difficulty of closing it again air-tight after each passage of a train.

Electric Telegraph.

Astonishing as the rapidity of railway transit may appear, it is not for an instant to be compared with that of the Electric Telegraph. This wonderful apparatus is now appended to every railway of importance, both for the purpose of conveying messages in connection with the working of the line, and as a means of correspondence for the public. Telegraphs so set in motion were invented by Cooke and Wheatstone about the year 1837, but have since undergone numerous modifications and improvements by Morse, Bain, Brett, Little, and others. As explained under ELECTRO-MAGNETISM, the invention depends upon the principle, that an electric

current can pass along a conducting-wire to any distance, and be made to move magnetic needles at any part of its course—these needles indicating or signaling according to some predetermined arrangement. The essential parts of the mechanism are, the *conducting wire* or wires, the *battery* which generates the electric current, the *signaling apparatus*, and the *mechanism for making and breaking the metallic contact* that completes the circle.

We shall briefly indicate the various steps in the process. The forms of batteries used for generating the electric current are very numerous; the one most generally employed on the Electric Telegraph Company's lines is that arranged by Mr Cooke, and known as the *sand battery*. It is on the principle of Wollaston's trough, with plates of copper and zinc, the spaces between being filled with dry and clean sand. To set it in operation, the sand is moistened with sulphuric acid. This form of battery possesses many advantages, requiring little attention, and remaining longer in action than the *wet battery*. In some telegraphs the current is produced by magneto-electric machines (see ELECTRICITY).

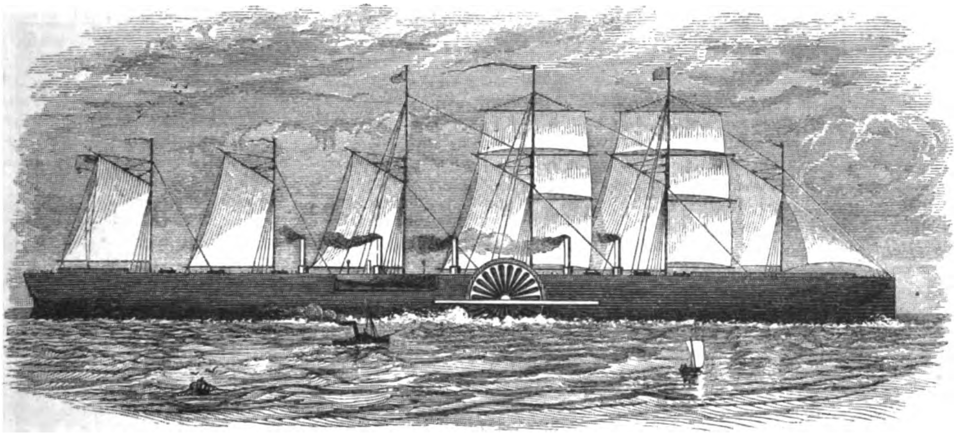
In this country, the telegraphic wires are suspended between a series of posts fixed in the ground by the side of the railway. In insulating the wires from the poles, a variety of methods have been introduced; the aim in all is to keep the points of contact dry. The most improved insulator is the green glass hollow cup. This is placed in an inverted position, and the support by which it is connected with the post is bent upwards, and fastened to the interior top of the cup by proper cement. The wire is passed round the exterior of the cup. To prevent corrosion, galvanised wire is generally used. In carrying the wires along the streets, they are placed in iron pipes, and insulated by a coating of gutta-percha; the tunnel wires are also insulated by this material. The electrical circuit is completed by connecting the extreme ends of the wires with plates of copper sunk some three or four feet in the ground. The earth thus forms one half of the circuit, the wires stretching from pole to pole the other. In submarine telegraphs, the wires, each coated separately with gutta-percha, are enclosed in a strong cable formed of spun-yarn and galvanised iron-wire.

The Signaling Apparatus.—A current of electricity being once established, there are various ways in which it may be made to produce a set of motions at will, at any part of the circuit. The *needle* signal is the one generally employed in this country. As has been already explained under ELECTRO-MAGNETISM, when a magnet, balanced on a pivot, is placed alongside the conducting-wire of a galvanic circuit, it turns at right angles to the wire whenever the current is made to pass; and the deflection is to the right or to the left according to the direction of the current along the wire. Two needles, then, are fixed on one axis, the one in front of a dial-plate like that of a clock, the other inside the frame; and they are so arranged that the needle outside, when undisturbed, remains perpendicular. A coil of the conducting-wire is now disposed round the interior needle, and the current being sent through the coil in one direction, the needles, both interior and exterior, are deflected, say to the right, and on reversing the current, the deflection is changed to the left. The contrivance by which the direction of the electric current is changed, is called a *commutator*, and is too complex for mere verbal description. It is sufficient to say, that by the simple motions of a handle, making and breaking contact between a number of metallic points, a succession of reversals of the current, and consequent alternations of the needle from right to left, and from left to right, may be effected with great rapidity.

As the movement of the handle may be made in London and the deflections of the needle take place in Edinburgh, it is evident that by agreeing to affix certain meanings to the deflections, a message may be conveyed instantaneously from the one place to the other. By fixing, for instance, that a motion to the right shall signify A, one to the left B, two to the right in rapid succession C, &c., the electric current may be made to spell any word that is wanted. In order to avoid too many repetitions of the deflections, two needles are generally employed. In the United States, the telegraph most in use is Morse's, in which the pulsations of the current guide the oscillations of a lever with a pencil attached, so as to make interrupted tracings on a moving strip of paper.

The decomposing powers of electricity are taken advantage of to produce an electric telegraph which prints its own messages. In Bain's printing telegraph, bands of paper, moistened with a mixture of sulphuric acid and prussiate of potash, are interposed in the electric circuit; whenever the current passes, the solution is decomposed, and a blue mark made. The alphabet is composed of a combination of short and long marks, produced respectively by instantaneous currents, and by others of short duration. 'These currents are sometimes sent by hand by mere making of contact; at other times, short and long holes are punched in a dry paper band, and this is drawn by clock-work between the metal point and cylinder which closes the circuit, and thus the current is cut off, when the sound part of the paper intervenes and passes, when the presence of a hole allows the part to touch the cylinder, and complete the circuit. The moist paper receiving the spots is made to move on at a like rate.' In House's and in Brett's printing telegraphs, the communications are impressed, not in cipher, but in common letter-press. A set of keys, similar to those of a pianoforte, are marked with the letters of the alphabet; and by pressing down the key marked D, for example, the letter D on a wheel at a distant station is brought into a position where it is impressed on a scroll of paper. Mr Brett states that an experienced clerk could manipulate upon the key-board upwards of 150 letters per minute. A still more wonderful form of printing telegraph is that of Bakewell, in which a positive facsimile of the message which the sender writes down at one end of the line is produced at the other. The decomposing powers of electricity are taken advantage of in this form, the moistened paper band being used; but the messages are written by means of a varnish on a tin foil, which is interposed between the point and the cylinder. The interruptions caused by the varnish-writing, break the electric circuit in those places, and cause a cessation of marking while the style or point is passing over each letter. As the style traverses several times over each letter or line of writing, the successions of interruptions produce an exact copy of what is originally written on the tin foil; the copy at the other end being written in a pale colour, on a ground of closely drawn blue lines. The cylinder on which the varnish-written message is wound, is made to revolve at the same rate as the cylinder at the other end of the line which receives the moistened paper.

The extension of the electric telegraph, has been yet more rapid than that of railways. Throughout Europe and North America, a net-work of these magic wires already unites all the chief towns, and ramifications are rapidly extending in all directions. Nor is the ocean an insuperable barrier, as in the case of railway-communication. The submarine cable unites Ireland to Britain, and Britain to the continent of Europe; Spezzia in Piedmont will soon be joined to Bona in Africa, by way of Corsica and Sardinia; and there is every prospect that, before a year elapses, a cable will be laid from Ireland to St John's in Newfoundland, which will complete the communication between the Old World and the New.



The *Great Eastern* Ocean Ship—screw, paddle, and sail.

MARITIME CONVEYANCE.

THE instruments of maritime conveyance are *ships*—a term which, though commonly applied to decked vessels only, may be made to include every species of craft, from the rude canoe of the savage to the three-decked man-of-war.* Their construction and equipment, their navigation and management when afloat, the building of docks and harbours for their reception, the erection of light-houses and beacons for their guidance; in fact, the whole science by which man is enabled to traverse the ocean, and bring the most distant regions, as it were, into local proximity, is one of superlative interest, and especially so to the inhabitants of an insular country like Britain. To a brief exposition of its leading features, as above indicated, we intend to devote the present sheet.

A notice of the details connected with the arrangement and construction of harbours, piers, docks, &c., will be found in the number on CIVIL ENGINEERING.

SHIPS.

Of the early history of ship-architecture little can be said of any importance. The buoyant property of water, particularly that of the sea, must have been soon observed by mankind; and therefore, beginning with rude skiffs and canoes, they would in time acquire sufficient experience and skill to form vessels of a larger size, and to guide them in the required direction by means of a rudder and sails. The cultivated nations of antiquity—Egyptians, Phœnicians, Carthaginians, and others—possessed ships for commerce and war, some of which were of large dimensions, and were moved either by oars or by the action of the wind on sails. But of these early vessels, as well as of those now employed by half-civilised nations, it is unnecessary here to speak; we proceed rather to notice the construction and character of ships formed according to the principles of modern and improved science.

The nicest and most difficult operation in ship-building consists in first forming a draught or model of the proposed vessel, or, as we may call it, the *plan* which the mechanics are to adopt and follow out. In forming this plan, the designer is governed by a consideration of the precise object to be attained. There are two classes of vessels—ships-of-war and merchantmen—and each must possess certain qualifications. In a ship-of-war the great object is speed, with ease of movement, and capacity to accommodate her crew, and to carry a sufficient weight of guns, stores, and provisions. One point, moreover, is especially to be looked to; this is, that the ship float high enough above water to run no risk of receiving waves or seas in her lower ports during action, when these holes must be necessarily open. In order to secure this, the constructer makes an estimate of the whole weight of the ship, including body, spars, armament, men, and munitions, and must so model the bottom that it will have displaced an equal weight of water when arrived at the desired depth. In the case of merchantmen, the primary consideration is to attain the greatest capacity to carry cargo, combined, as far as possible, with safe and easy movements and rapid sailing.

The English excel in ship-building, but in some respects they are outdone by the Americans, whose packet-ships carry enormous weights, while they are noted for their speed. Among the admitted and well-established principles of construction is the leading one, that the greatest breadth must always be before the centre, and consequently the *bow* or front be more blunt than the *stern* or hinder part. Abstractly, it would seem most important that the bow should be the sharpest, so as to cleave the water with the least possible resistance; but experience has proved that it is far more essential to facilitate the escape of the displaced water along the side of the vessel; for when once a passage is opened for the ship, the fluid tends to reunite behind the point of greatest breadth, where, instead of offering resistance, it presses the ship

* The etymology of the word shews what the thing was in its origin. *Ship* is only another form of the word *skiff* (Ger. *schiff*, a ship), and is evidently from the root of the verbs to *shape*, and to *scoop*, or 'hollow out.' The original 'ship,' then, was simply a tree 'scooped' out.

'orward, and fills up the space constantly opening behind ier. The principle is evident in the form of the duck ind other aquatic animals, which are uniformly broadest n front, and gradually diminish to the tail. As it is, hen, less essential that a ship should be sharp forward han aft, there is a further advantage in having the bow 'ull towards the edge, that it may check her in descending into the waves, not abruptly, but gently—pitching, or rising and falling endwise, being the most dangerous o hull and spars of all a vessel's movements. Though harpness towards the stern-post is vitally essential to ast sailing, yet care must be taken to leave the buttock 'ull towards the surface, in order to check the stern gently in descending, and when scudding before a gale, o lift it in timely season on the arrival of a sea. To hit he exact mean in these respects, so as not to retard the ailing on the one hand, nor endanger the ship on the other, requires all the skill of the architect.

There must, likewise, be a due correspondence between he general bulk of the vessel and its length and breadth: he whole must be properly proportioned. If unduly ong, speed may be gained, but there is a difficulty of urning, and also of rising to escape the breakings of the ea; long ships, therefore, are apt to roll and to cut hrough waves, instead of breasting them, by which their afety is perilled. When a ship is unduly short for its general bulk, it is apt to pitch, which is equally dangerous; ence the greatest care is required to proportion the arious dimensions.

As many of the requirements in the construction of a hip do not harmonise with each other, the skill of the naval architect is shewn in duly proportioning them to one another, ascertaining that which is chiefly desiderated, and carrying this out without impairing the efficiency of he others. The following is a description of the peculiarities of a form of ship which is considered to meet all he usual requirements. 'The body of a ship above its niddle has nearly the form of a portion of a hollow cylinder, with its axis horizontal, and its convex side lownwards. Above the surface of the water on which it loats, the sides are curved, so as at the head to have, in a horizontal direction, the form of a Gothic arch, more or less acute. The breadth diminishes gradually towards he stern, which above water is either a plane surface nearly perpendicular to the ship's length, or, according to Sir Robert Seppings's construction, curved so as to have a horizontal section nearly the form of a semi-ellipse. Below the surface of the water, the body of the ship is curved in a horizontal direction towards the head and stern, so as to terminate at those places in angles which diminish from that surface downwards; and thus a vertical section taken perpendicularly to the length of he ship, at some distance from the middle towards either extremity, presents on each side the form of a curve of contrary flexure.' The researches and experiments of Mr Scott Russell on the 'form of least resistance at high velocity,' are considered by authorities to have an important practical bearing on the form and motion of vessels.

In commencing to design a ship, the first duty of the architect is to ascertain her displacement (see HYDROSTATICS), or the weight of water which she displaces, which is that of the ship itself. From this her general proportions are deduced, the bulk being in proportion to he length, breadth, and depth. These being known, the nidship section, or transverse vertical section, at its widest part, is next decided on; the load-water section, or horizontal section at the surface of the water, being he next point claiming attention. Other vertical transverse sections are also laid down, at parts of the ength where the form varies from that of the midship section, together with the depth below the water-line. These points being settled, a series of drawings on a small scale are made. They are generally three in number; one shews the vessel as cut in two, from stem to stern, and is called the 'sheer-plan;' the second is a plan taken horizontally at the line of greatest breadth, and is termed the 'half-breadth plan;' the third shews the midship section, and is termed the 'body-plan.' From these drawings enlarged drawings are made, in what is called the 'drawing-floor' or 'mould-loft,' to the full size, the lines being laid down on the floor. The exact shape and position of the timbers are here shewn to guide the workman in all the details.

All essential preliminaries being settled, the ship is begun to be constructed; and this is always done in the yard of a ship-builder, close by the water's edge. The wood considered to be best adapted for ship-building is oak, pine, teak, elm, or beech; and whichever is employed, it requires to be strong, well seasoned, and dry; the greater part, likewise, should be bent or crooked, to suit the curves and angularities in the structure; and for this end, growing timber is often constrained to assume particular forms. The *keel*, which is the lowest part of the vessel, and corresponds to the backbone of an animal, from which the ribs or *timbers* spring, is formed and laid first on a slip and blocks set for the purpose. As the framework proceeds, all parts are firmly bolted and riveted together, and the whole is finally covered with the planking in even lines from bow to stern. When it is necessary to bend a plank for either the bow or stern, it is heated by steam, and then forced into its place by screws and levers. The planks are fastened to the ribs by *treenails*, or wooden pins, and the plan is followed of allowing a seam or space between each plank, which is filled up or *calked* with oakum, and the whole is smeared with pitch. In some instances, the bottom is further secured by sheathing it in sheets of copper. Meanwhile, the interior beams and partitions have been placed; and when duly prepared, the vessel is *launched*, or shot into the water by an easy movement, down the inclined plane on which it rests. After launching, the rudder or *helm* is shipped. The rudder is a wooden apparatus placed at the stern of the ship, a large portion being in the water; and by means of it, the vessel is steered and turned about at pleasure. The steering part is on deck, and consists either of a simple lever, called the *tiller*, or of a wheel placed perpendicularly, and connected with the tiller by chains and pulleys. The principle on which the rudder acts is very simple: the object is to turn the vessel; and to whatever side the inclination is to be made, the rudder is caused to present an obstacle to the water in that direction.

The masts of the vessel are now set; and the *spars*—comprehending the bowsprit and yards, and also the rigging—are attached. The spars of a ship are not abandoned to their own unsupported strength, but are sustained by what is called the *standing-rigging*, which consists of strong well-spun ropes, or, in some recent instances, of iron wire twisted into strands of the requisite thickness. Besides this, there is the *running-rigging*, which consists of the tacks and sheets that serve to spread the sails, the halliards, traces, lifts, clew-lines, and all other ropes used in making, taking in, or manœuvring the sails. In the construction of both hull and rigging there is a vast amount of bolting, nailing, splicing, and so forth, much of which is likely to be now superseded by the use of Jeffrey's marine glue—a substance of such tenacity that planks joined by it have been found to give way invariably in the solid wood, and not at the junction. Masts marine-glued, and without hoop or bolt, have been tried, and, after the exposure of a tropical voyage, have returned sound and strong as on the day they were constructed. Indeed, so invincible is the tenacity of this compound, that the possibility of constructing a hull without bolt or treenail has been soberly asserted.

The sails of a ship are sheets of canvas bent to the yards, and fore-and-aft sails traversing on stays or bent to gaffs. Let us proceed to describe an entire suite, beginning forward, and referring to the subsequent

figures :—On the extremity of the bowsprit is the *flying-jib*, a three-cornered sail, which goes from the end of its boom upward along its stay, leading to the foretop-gallant-mast-head, and confined to the stay by rings of wood or iron, called the *hanks*. It is hoisted by means of the halliard; hauled down by a down-haul; and when up, is trimmed to hold the wind by a sheet or rope leading to the forecastle. The *jib*, which leads from its boom to the foretop-mast-head, is of similar form, and so is the *foretop-mast-stay-sail*, running from the bowsprit end towards the mast-head. On the fore-mast we have the *fore-sail*, bent to the fore-yard, and spread at the foot by means of tacks and sheets; above it, the *foretop-sail*, bent to the top-sail-yard, by means of which it is hoisted aloft, while its lower corners are spread to the extremities of the fore-yard; next the *top-gallant-sail*, bent to its yard, and sheeting home to the top-sail-yard; and so with the *royal* and *sky-sail*. All these sails are turned at pleasure, to be presented to the wind, by means of braces attached to their yard-arm, and leading to the mainmast. The mainmast is furnished with a similar suite of sails, somewhat larger; the mizzen-mast also, though smaller than either, instead of a square-sail on the lower part of the mast, has a *gaff-sail*, hoisting up or down abaft the mast. Some ships have similar gaff-sails on the fore and main masts, which are found of great use in gales of wind, as a substitute for storm stay-sails. Most carry, also, light stay-sails between the masts; but they are very trouble-some. *Studding-sails*, spread beyond the square-sails like wings, are found useful when going before the wind. The perfection of equipping a ship with spars, rigging, and sails, consists in so disposing them, that in a whole or full sail breeze the centre of effort of all the sails will be in the same line with the ship's centre of rotation; or that the efforts of the forward and after sails to turn the ship will be exactly balanced, as not to require any continued assistance from the rudder in either direction.

Such is a brief outline of the construction of a common decked vessel as regards hull and rigging. It must be remembered, however, that different modes are adopted according to the kind of service for which the craft is intended, and that general improvements are occasionally being made in naval architecture. Thus, independently of a difference in material, some arrange the timbers or framework in such a manner that they shall form the main strength of the vessel; while others, following a cheaper and less scientific course, plant the timbers perpendicularly and sparsely, thereby throwing a great, if not the greater, portion of the strain on the outer planking. Again, much depends on the securing of the masts, which, when under press of canvas, act as powerful levers on the parts of the hull to which they are attached. Instead of resting these only upon steps, strong platforms, which diffuse the pressure on all sides, are now generally used, and by this means a fertile source of leakage extinguished. Round sterns, which can be constructed with all the strength of the bow, are now also preferred to the old square and massive but weak stern; and further, the breadth of beam, which adds stability to the whole fabric, has of late been considerably increased.

The principal ship-building ports in Britain—laying aside consideration of the government dock-yards—are London, Sunderland, Newcastle, Liverpool, Hull, Greenock, Glasgow, Aberdeen, Yarmouth, &c. With respect to the classification of British vessels, Mr M'Culloch remarks: 'Until very recently, ships, how much soever they might differ in other respects, were classified at Lloyd's (the office of the Society of Under-writers, and great centre of shipping affairs) with reference solely to their age and the place where they were built. Thus, supposing two ships were launched about the same time in the Thames, the Wear, or anywhere else, they were enrolled together in the *highest* class in Lloyd's Register, and stood there for a certain number of years, how different soever they might have originally been, or how different soever they might afterwards become! And underwriters, thus seeing them standing together, and having no other test of goodness to which to refer, insured and employed the one on the same terms as the other! It is unnecessary to dwell on the preposterous absurdity of such a system. Practically, it operated as a high bounty on the building of defective, or what is called *slop-built* ships; and there can be no doubt that it tended materially to depreciate the character of our mercantile marine, and to multiply shipwrecks to a frightful extent. We are therefore glad to state that a new system of classification has been adopted, by which the place of vessels on the register will be made to depend, not on their age, or the port where they were built, but upon their actual condition.' The several classes are marked by the letters A, Æ, E, and I, which have reference to the state of the hull; and by figures which indicate the condition of the stores and equip-ment. Thus, 10 A1 denotes a ten-years' ship of the first description of the first-class, with stores well and sufficiently found. Steam-ships are similarly classified, but require to be surveyed *twice a year*.

With respect to the methods in use for ascertaining the tonnage of a ship, or, in other words, her capability for stowing and carrying of cargo—from the discussion recently entered into on the subject, there seems great reason to desire the establishment of a scientific principle by which this could be easily and uniformly obtained, the whole subject being evidently surrounded with diffi-culties. Thus, in the act of 1854, the tonnage admea-surement is based on the internal capacity of the vessel; but the system is so complicated, as to render the practi-cal operation whereby the results are obtained a mystery unintelligible to everybody excepting those who make it a professional study. The consequence is, that this, the legal system of admeasurement, is rarely adopted as 'the base of mercantile contracts for the purchasing and building of ships;' but the old law of 1773, known as 'builders' measurement,' with all its glaring defects, is that generally followed. The following is the law here alluded to: 'The length shall be taken in a straight line along the rabbet of the keel of the ship, from the back of the main stern-post to a perpendicular line from the fore-port of the main stem, under the bowsprit; from which subtracting three-fifths of the breadth, the re-mainder shall be esteemed the just length of the keel to find the tonnage; and the breadth shall be taken from the outside of the outside plank in the broadest place of the ship, be it either above or below the main walls, exclusive of all manner of doubling planks that may be wrought upon the sides of the ship; then multiplying the length of the keel by the breadth so taken, and the product by half the breadth, and dividing the whole by ninety-four, the quotient shall be deemed the true con-tents of the tonnage.' The term 'tonnage' is theoretic-ally meant to convey the amount of sea-water which the interior capacity would contain. Under the new law, it 'has no reference whatever to the *tons-weight* which a ship will carry; but means that a ship of given tonnage has the available internal capacity of 100 cubic feet for each ton of *nominal tonnage*.'

The impetus given by the rivalry of steam-navigation has led to the construction of sailing-ships possessing surprising power and speed. Great Britain and America are honourably competing for superiority in the construc-tion of 'clippers' having these properties; and every year adds to the number of successful examples—such as the *Sovereign of the Seas* (2420 tons), in 1853; the *Tayleur* iron sailing-ship (2500 tons), in the same year; the *Great Republic* (3400 tons), in 1854; the *Donald M'Kay* (2590 tons), in 1855; and many others, British and American.

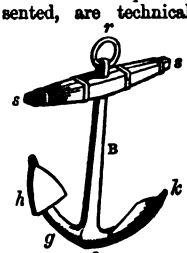
Cables, Anchors, Lightning-conductors, and Buoys.

By the substitution of iron link for hemp cables, due to the late Sir Samuel Brown, an important benefit was

bestowed on the shipping community. The old hemp-cables were liable to rapid decay, and to being cut on rocky bottoms, or suddenly snapped by the pitching of the vessel. The invention of the chain-cable has been characterised by the highest authority as a 'vast improvement'—one of 'the greatest effected for the shipping interests, and the preservation of life and property.'

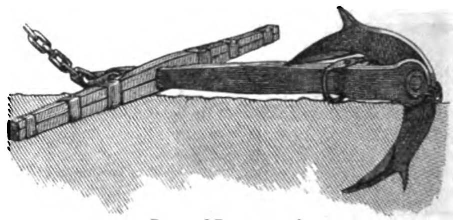
The retarding apparatus of the vessel consists of heavy iron instruments, called anchors, of which each vessel has usually more than one. Large ships carry the following suite of anchors: 1. The *sheet*-anchor, which is the largest, and only used in the case of violent storms; 2. Two bower-anchors—namely, the *best bower* and *small bower*, so called from their situation at the bows; 3. The *stream*-anchor, the *kedge*, and *grappling* or *grapnel*. The last three are often used for moving the ship from place to place in a harbour or river. Each anchor is let down by a strong cable of iron or rope, and is lifted by means of the windlass placed on deck. To the cable, when in the water, a *buoy* or floating object may be attached, to shew where the anchor has been let down; and to save time, or in an emergency, the anchor and cable are sometimes left, while the vessel proceeds, the buoy serving to point out where the anchor may be recovered. The anchor is said to be *a-peak* when the cable is perpendicular between the hawse and the anchor; it is said to *come home* when it does not hold the ship; it is said to be *foul* when the cable gets hitched about the flukes. *Riding at anchor* is the state of the vessel when moored or fixed by the anchor; *dropping* or *casting anchor* is letting it down into the sea; *weighing anchor* is raising it from the bottom.

The several parts of a common anchor, here represented, are technically designated as follows: The



straight bar B, to which the cable is attached, is called the *shank; r*, the *ring;* the cross bar *ss*, fixed at the free extremity of the shank, the *stock;* the upper end of the shank, the *small round;* the extremity c, where the shank and arms unite, is called the *crown;* the angle formed by the arms and the shank is termed the *throat*, and generally stands about 56°. The arms consist of three parts—the *blade* (*g*), the *palm* (*h*), and the *bill* (*k*). The palm or fluke is made of a flat triangular shape, the apex of which is prolonged so as to form the bill or peak. However large and ponderous, anchors are all formed of bar-iron, welded and wrought together by hand-hammering. Their fabrication, which is extensively carried on in Britain, requires great skill and care.

In addition to the common anchor represented above, there are various other forms in use, each laying claim to some peculiar superiority. Thus, the grapnel has three or four arms instead of two; the mushroom anchor (so called from its shape), much used in the East Indies, has an entire holding edge, being shaped like a mushroom or bowl. When we consider the importance of the duty an anchor has to perform, and the value of the lives and property dependent for their safety upon its capability to perform this under all circumstances, we can easily understand the anxious endeavours of inventors to contrive a form which combines at once strength to resist great shocks and strains, and a facility to take and retain hold of the anchorage-ground. Amongst those who have directed their attention to this important part of naval mechanism, special mention should be made of Lieutenant Rogers and the Messrs Porter—the forms of anchor introduced by them have been proved to be great improvements on the old. Lieutenant Rogers is the patentee of three forms, two of which have one arm only, the third has two. The peculiarly distinctive feature of these is the employment of a hollow iron shank, by which, with less material than in a solid one, a greater strength is obtained. The anchor considered by the jury to be the best, at the government trial at Sheerness, was that on Porters' patent principle, modified by Mr Trotman, to which we have already alluded, and which, from its novelty and decided efficiency, is worthy of brief notice here.



Porters' Patent Anchor.

The anchor is formed in two distinct parts, the arms separate from the shank. The part forming the arms is made in one piece, so that no crossing or welding is required. The second peculiarity is the attaching of the curved arms to the shank by means of a strong bolt. To admit of this, the end of the shank is made forked, and the piece forming the arms being inserted between the two projections, the bolt passes through all three. In this way, the arms are not held fixed in one position, but allowed to vibrate on the bolt. The third, and what may be called the distinguishing peculiarity, is the adaptation of projecting horns or spurs to the back of the flukes, or, more properly, at the back of the arms, a little above the fluke. It is upon these spurs or horns that the peculiar penetrating power of the anchor depends. When first canted, it rests upon the stock, the extremity of the shank, and the horn or spur; the horn acting as a fulcrum, the strain upon the cable brings down the point of the fluke to which it is attached. This strain continuing, the arms move in the cheeks of the shank until the tip of the upper fluke presses down upon the upper side of the shank. The position of penetration of the lower fluke being thus obtained, the effect of the continued strain is to cause it to enter the ground. When entered to its full depth, the shank lies flat out parallel to the ground, while the upper fluke is brought close to its upper side. Thus, while the strain is acting upon the anchor, the major portion of the resistance is removed from the bolt on which the arms vibrate, and transferred to the part on which the upper fluke presses. By this arrangement the strain is divided more equably, the leverage brought nearer to the ring, and the anchor thus calculated to resist the various shocks and strains to which it is subjected.

A most important adjunct to ships is an efficient system of lightning-conductors. Under the old system, a small chain or rope of wire was temporarily applied to the mast or rigging; but the peculiar circumstances under which ships are necessarily placed, prevented it from being efficient. The new system introduced by Sir W. Snow Harris of Plymouth, has been eminently successful, and is being largely introduced. The following is a description of the principle and mode of carrying it out: 'Sir W. Snow Harris conceived the idea of making capacious metallic conductors an integral portion of the masts and hull of the vessel, so as to bring the general fabric into that perfect conducting or non-resisting state it would assume in respect of the matter of lightning, supposing the whole mass to be metallic throughout. This he has effected by incorporating with the masts and hull a series of copper plates, so arranged as to meet all the varying conditions of the spars, and so tied together, that an electrical discharge, striking upon any part of the vessel, cannot enter upon any circuit of which the conductors do not form a part, and thus the ship is preserved from the effects of lightning

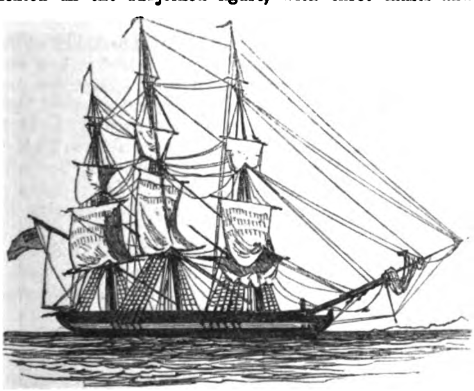
at all times and under all circumstances, without the officers and crews being in any way concerned in the matter.'

Buoys are vessels either formed of wood, cork, or some light substance, moored or anchored so as to float over a certain spot, in order to indicate the situation of a shoal or sand-bank, and thus mark out the course which the ship ought to follow; or they may be constructed of large blocks of wood, clamped with iron, and furnished with rings, to which vessels may moor themselves in rivers or in harbours. When used for the former purpose, they are usually hollow vessels, barrel-built, in the form of a cone, of large dimensions, so that they may be seen at a distance, and generally painted of some particular colour, that they may be more readily distinguished from one another. Mooring-buoys, on the other hand, are generally solid blocks, kept in their places by heavy anchors or sunken weights. As these are liable to be dragged, various methods of secure fixing have been proposed, but none with the same likelihood of success as the 'screw pile' of Mr Mitchell, to be hereafter described.

Referring to NAVAL AND MILITARY ORGANISATION for an account of ships-of-war, we proceed to describe

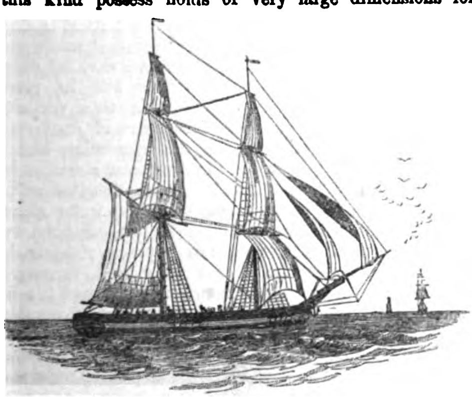
Merchant Sailing-vessels.

Vessels employed in trade, or merchantmen, are of numerous sizes, shapes, and modes of rigging—these depending not merely on the peculiar trade for which they are destined, but on the taste and whims of the owners. The largest is the ship-proper, as represented in the subjoined figure, with three masts and



Merchant-ship.

square sails, but having only an upper deck. Vessels of this kind possess holds of very large dimensions for



Brig.

stowing goods, and their burden is from 1000 to 1500 tons. When destined for long voyages, and in good service, as they generally are, order and discipline are maintained on board with almost as much severity as in the regular navy. The ships employed in the China and East India trade are the largest belonging to this country; those in the West India trade rank next; then the whale-ships, those in the Baltic and Canada trade, the Mediterranean trade, the coal and general coasting trade; and so on in descending gradation.

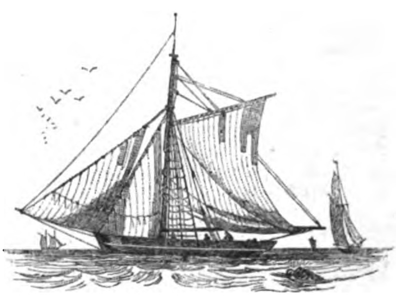
Next beneath the class of ships is that of *brigs*. A brig, of which we here present a sketch, has only two masts, but it possesses square rigging, like a ship. Brigs are handsome and roomy vessels, varying from 400 to 800 tons burden.

With brigs, square rigging terminates, and we now come to classes of vessels in which the rigging is of a different character. At the head of these stands the *schooner*, a vessel with two masts, and capable of carrying a large press of canvass. A schooner is in general

Schooner.

sharp built, with masts of considerable height, and with small topmasts and fore-and-aft sails. The rigging, however, is various, though normally as above represented.

Vessels possessing only one mast are either *sloops* or *cutters*, both distinguished by their tall mast and



Sloop.

extremely large mainsail, which projects beyond the stern. Sloops are chiefly engaged as coasting-traders, and are of all burdens, from 100 to 500 tons. The class of sloops employed to carry goods and passengers between distant ports are ordinarily styled *smacks*. There are schooners and sloops of war carrying from ten to twenty guns; they are generally employed in the custom-house service, and adapted for quick sailing.

A *lugger* is a small kind of vessel, but carrying three masts and a running-bowsprit, with sails of the form called lug-sails. A *brigantine* is a brig which can be either sailed or rowed. A *xebec* is a light swift-sailing vessel, of three masts, and a long prow, peculiar to the ports of the Mediterranean. A *galley* is another vessel peculiar to the ports of the Mediterranean; it is low built, and carries two masts, but depends chiefly on

being rowed with oars; condemned criminals are often sent as a punishment to row these galleys. A *yacht* is a small vessel designed either for state or pleasure. America has recently contested with Great Britain the honour of producing yachts having a speed far exceeding any before known. All the preceding classes of vessels possess decks. Small open vessels, not possessing the accommodation of a deck, are of the class of *boats*, of which there are many varieties—as the long-boat, pinnace, wherry, gig, barge, and so forth. Boats are mostly built with the side-planks lapping over one another; and this, which is called being *clinker-built*, gives them greater buoyancy and strength than if built in the manner of ships.

In every class of merchant-vessels the prime object is to accommodate as large a quantity of goods as possible, and therefore comparatively little space is occupied with accommodation for either the captain or his crew. If the cargo be light, such as cotton, *ballast* is required to be put on board; this consists of sand, shingle, or any other heavy material, which is placed lowest in the hold, in order to balance the vessel, and give it due hold of the water. In the royal navy, iron ballast alone is used, in pigs of nearly three hundredweights. This has the advantage of lying in small compass; but in consequence of its great weight, it tends to give excess of stability, which renders the vessel uneasy from the suddenness of the motion. This defect is remedied by *winging* the ballast, whereby its centre of gravity is raised. For the like reason, in stowing the ballast, it is tapered to a point at the fore and after extremities. Iron ballast, from its greater cleanliness, is more healthy for the crew than that of other materials. When a ship has no other loading, she is said to be *in ballast*. In stowing cargo, care is taken to preserve the *trim* of the vessel—that is, to keep it upright, and also equally balanced fore and aft. The connection between the motions of a ship and her stowage (whether of ballast or cargo) has not, however, been sufficiently analysed to lead to the discovery of any direct rule on this very important point.

Merchant Steam-vessels.

To Scotland is due the honour of having solved the problem of steam-navigation, although America was the first to prove the commercial advantage of the system. A few unsuccessful attempts had been made in earlier years in England and France; but the real start to steam-navigation was given in Dumfriesshire. Mr Patrick Miller, a banker of Edinburgh, who had a country residence at Dalswinton in Nithsdale, after much speculation on the possibility of navigating a vessel without oars or sails, prepared in 1787 a small triple boat, having rotary paddles in the two interspaces, driven by a crank worked by four men. Mr Taylor, preceptor to Mr Miller's sons, suggested a trial of steam-power instead of manual power; and it was then agreed that a new boat should be fitted with a steam-engine under Taylor's superintendence, by William Symington, an ingenious mechanic: the engine to be made by George Watt, brassfounder of Edinburgh. All this being accomplished, the first steam-voyage was made on a small lake at Dalswinton, on the 14th of October 1788. In this instance, the steam-engine worked *one* paddle in the interspace of a twin-boat. On Christmas-day 1789, another steam-boat was propelled, at the rate of seven miles an hour, on the Forth and Clyde Canal; it was made for Mr Miller, was sixty feet long, and was fitted with an engine made under Symington's care at Carron. As a commercial speculation, it was abandoned, through fear that the undulation produced by it would injure the banks of the canal. Miller and Taylor effected nothing further in steam-navigation; but Symington, many years afterwards, took out a patent under which a steam-boat called the *Charlotte Dundas* was tried for a time on the same canal, in 1803. Henry Bell, an ingenious mechanic of Glasgow, who had witnessed the experiment of 1789, pondered on what he saw, and took up the subject at a later date, after Symington had abandoned it. It was not, however, until 1811 that he placed a small steamer in operation on the Clyde; this was the *Comet*, of twenty-five tons burden and three horse-power; small as it was, it steamed down the Clyde against a head-wind at five miles an hour. Meanwhile, Robert Fulton, an American of great ingenuity and energy, taking up an unsuccessful patent of Chancellor Livingston's, adding to it various details given to him by Bell concerning Miller and Symington's twin-boat, and supplying the rest by the resources of his own mind, placed a steam-boat called the *Clermont*, of 160 tons burden, on Hudson River, in 1807; it steamed 110 miles in twenty-four hours. Space is wanting here to discuss the relative merits of Miller, Taylor, Symington, Bell, and Fulton, as inventors in steam-navigation; all we can say is, that society owes to those ingenious individuals a debt above all price.

Thenceforward the progress of steaming was steady and rapid. The first steam-boat on the Thames, the *Margery*, seventy tons burden, and fourteen horse-power, ran between London and Gravesend in 1816; from this small beginning, forty years of improvement have developed a fine system of Thames steam-navigation. The Clyde, however, has been still more associated with these improvements. After various minor trials between 1811 and 1818, Mr David Napier sent a steamer from Greenock to Belfast in the last-named year; it was the *Rob Roy*, of ninety tons and thirty horse-power, that thus had the honour of being the first vessel to steam across a sea. He next planned the *Talbot*, to run between Holyhead and Dublin; and soon afterwards he established a line of steam-ships between Glasgow and Liverpool. In America, the length and commercial importance of the rivers enabled that country to take a lead it has ever since maintained in *river*-steaming. About the year 1813, Mr Stevens made a steam-voyage from New York to the Delaware, along the Atlantic sea-board. In 1819, the *Savannah* crossed the Atlantic from New York to Liverpool; but she being chiefly propelled by her sails, this cannot be called a steam-voyage. Later stages of progress we shall notice presently in connection with the chief steam-shipping companies.

Referring to the article STEAM-ENGINE for a description of the various kinds of engines used for marine purposes, we will proceed to notice the *paddles* and *screws* whereby steam-power is rendered available.

Where paddles are employed, they consist of two wheels attached to the ends of a shaft running across the vessel, which shaft receives motion from the engines. The paddle-wheels hang over the sides of the vessel, and dip into the water. They have boards or *floats* at the circumference, parallel with the axis; and it is to the resistance offered by the water to the movement of these boards that the motion of the vessel itself is due. When each board is firmly fixed in position, it enters and leaves the water obliquely, exerting less working effect than if it entered and left the water with its plane vertical. Various modes of obtaining this verticity have been introduced, under the names of *feathering* paddles, *cycloidal* paddles, &c. A somewhat higher speed is attained in many of the American steamers by dividing each float-board into three parts longitudinally, in such way that each part may enter the water alone, thereby lessening the amount of beating or splashing.

Paddle-steamers, however, are rapidly yielding in favour to *screw*-steamers, except where high velocity is needed. The chief points of superiority are that, if sails be also used, the screw can be unshipped in weather favourable for sailing; that steam and sails can be used jointly in moderate winds; that less fuel need be taken, and less used; and that the absence of paddle-boxes is a great advantage, especially for war-steamers. Although screw-propellers had been theoretically advocated much earlier, it was not until 1836 that a method, patented by Mr J. P. Smith, came to be taken up in earnest by

engineers. His plan consisted in placing the screw or fan in a square aperture in the 'dead-wood' immediately in front of the rudder. The screw is made to rotate on a horizontal axis by a steam-engine, and drives the ship along by the resistance offered by the water to this rotation. Sometimes the screw consists of one thread, making one turn round the shaft or axis; sometimes of two or more threads, each making only a portion of a complete turn: the curvatures and adjustments being very varied, and the best form being still an unsolved problem. Screw-steaming having been found very useful as an auxiliary to sailing, engineers have adopted means of placing the screw out of the way when not wanted, since it would obstruct the ship's motion if immersed in the water without rotating. A new mode of propulsion has recently been brought forward by Mr Ruthven, in which the power of a centrifugal pump, worked at a high velocity by steam-power, is employed to force a current of water through nozzles placed at each side of the vessel: the resistance of the sea or river to this current drives on the vessel, by reaction.

Iron, as a material for ship-building, has come very extensively into use since the great employment of steam-propulsion. It is preferred to wood on account of its superior buoyancy, the facility of working it, its greater tenacity, and its greater cheapness for large vessels. One especial advantage is in the facility offered for the making of bulkheads, partitions, or transverse iron walls in a ship, whereby the interior is divided off into separate water-tight compartments. The Board of Trade returns shew how rapidly iron steamers are taking the lead of those built of timber. In the year 1855, of 233 steamers built in the United Kingdom, no less than 195 were of iron. The British-built steamers of all kinds, registered in the ports of the United Kingdom on the 1st of January 1856, were 1674, presenting an aggregate of 380,635 tons, or an average of about 230 tons. Our sailing-ships, on the same day, numbered 24,274, of 2,968,699 tons, or an average of about 122 tons.

Most of the improvements in steam-ships have been introduced under the auspices of the ocean mail companies. A company was formed at Bristol in 1836, to establish a mail-steamer from that port to New York; it was calculated that a steam-ship might make the outward voyage in twenty days, and the homeward in thirteen; instead of thirty-six and twenty-four days, as needed by the sailing-ships of that period. The *Great Western*, of 1340 tons, and two engines of 225 horse-power each, was accordingly built, under the engineering superintendence of Mr Brunel. Triumphing over predictions of failure, this steamer crossed the Atlantic in safety in 1838, under the command of Lieutenant Hosken. The success was mainly due to the power of carrying coals—namely, 600 tons—sufficient for the entire voyage of 3000 miles; of this quantity, 450 tons were consumed. The voyage was made in fifteen days, between April 8 and April 23. In the same month, the *Sirius* made a voyage from Cork to New York in nineteen days, between April 4 and April 23; but she was aided by sails; so that the problem of transatlantic steaming was really solved by the *Great Western*. Between 1838 and 1844, this fine vessel crossed the Atlantic eighty-four times, the average of the voyage being 14½ days. The same company afterwards built a much larger steamer, the *Great Britain*, which, after being stranded on the Irish coast, was purchased by a Liverpool firm, and placed on the Australian route. The *President*, another Bristol steamer of large size, was lost at sea; and the *British Queen*, a fourth, was sold to the Belgian government.

In July 1840, the Cunard mail-steamers began to run between Liverpool and Halifax; the first three employed were the *Britannia*, *Acadia*, and *Caledonia*, each about 1140 tons, with engines made by Mr Robert Napier of Glasgow; but larger vessels were built at a later date, such as the *Hibernia* and *Cambria*, of about 1420 tons each; and the *America*, *Niagara*, *Europa*, and *Canada*, of about 1830 tons each. Urged on by competition from other quarters, the Cunard Company built still more powerful and magnificent steamers. The Collins Company, of American formation, commenced ocean-steaming in 1850; their steam-ships *Atlantic*, *Pacific*, *Arctic*, and *Baltic*, were built to excel the Cunard line; while the latter, building the *Asia*, *Arabia*, *Persia*, and other noble vessels, resolved to maintain the precedence they had gained. Many of these superb steamers have cost more than £100,000 each, and exceed 3000 tons register. One of the Collins steam-ships, the *Arctic*, was unhappily wrecked near Newfoundland in 1854, with a loss of 300 passengers and crew. The grandest of these Atlantic steamers, the *Persia*, which made her first voyage in 1856, is 3600 tons register. So wonderful have been the improvements wrought by this competition, that a transatlantic voyage has become practicable in ten days. All the voyages of both companies in 1856, outward and homeward, presented an average of twelve days' duration for each.

Previous to 1836, the steam-route from England to India was very incomplete; but in that year the Peninsular and Oriental Company was established, to place the transit on a better footing, by having steamers from England to Alexandria, land-transport to Suez, and other steamers from Suez to India. Operations commenced in 1838; and during nineteen years, the ships employed have been gradually increased in size and power, and the route so extended as to include Singapore and China as well as the India ports. In the first ten years, the company built and employed twenty-six steamers, ten of iron, and sixteen of wood; the largest of these were the *Precursor*, of 1817 tons; the *Bentinck*, of 1974; and the *Hindostan*, of 2018. Since the year 1848, a fleet of magnificent large steamers has been added. One of the most celebrated was the *Himalaya*, an iron screw-steamer of 3550 tons, which began its career in 1854; it was bought by the government as a troop-ship some months afterwards, and was employed with great advantage during the Crimean war: whereupon the company built the *Pera*, launched early in 1856.

In 1842, mail-steamers were established to run from Southampton to the West India Islands; and the line has continued during fifteen years in the hands of the same company. The steamers, mostly named after rivers, have been gradually replaced by others of greater tonnage, as the trade extended. The *Thames*, *Trent*, *Medway*, *Teviot*, *Severn*, *Dee*, *Avon*, and *Clyde*, placed upon the route during the first ten years, were all between the limits of 1666 and 1886 tons; but since 1851, other steamers of much greater magnitude and splendour have been built. One of these, the *Amazon*, was burned on her first voyage out, in January 1852; and another, the *Demerara*, was stranded while being towed from the builder's yard at Bristol. The *Atrato*, an iron paddle-steamer of 3460 tons, gained great celebrity in 1855 and 1856 by making the quickest voyages ever known to and from the West Indies. One of the finest steamers of this line, the *Tyne*, was stranded on the Dorset coast in January 1857.

Steam-voyages to Australia have not, down to the beginning of 1857, been commercially successful—in part through indecision of the government, and in part through engineering causes presently to be explained. A company started vessels on this route in 1852. The first voyage was made by the *Australian*, a Clyde-built iron steamer; she stopped at four places to take in coals, and reached Melbourne, about 12,000 miles distant, in ninety-one days. The *Argo*, and other steamers belonging to the same company, afterwards ran the distance in sixty-five to seventy days. A fine screw-steamer, the *Crœsus*, of 2500 tons, started from England to Australia in 1854. In the same year, the *Golden Age*, an American steamer, crossed the Pacific from Sydney to Panama, being the first steamer that did so: she made

this voyage of 7950 miles in thirty-nine days, including six days' detention at Tahiti. In the same year, also, was effected the first circumnavigation of the globe by steam; the *Argo* having gone to Australia round the Cape of Good Hope, and returned round Cape Horn, each voyage being made in about sixty-five days. The Admiralty has entered into a contract for mail-service to Australia in 1857, by clipper-ships with auxiliary screws. The efficacy of the screw for ocean-steaming was mainly demonstrated by the General Screw Steam Company, connected chiefly with the African and Mediterranean routes.

Nothing can better shew the opinion of ship-builders and companies concerning the advantages of great length of hull in attaining speed, than the following list of six steamers, built at six different dates:

	Length.	Breadth.
1825 Enterprise (built for India), . . .	122 ft.	27 ft.
1835 Tagus (first Mediterranean steamer), .	182 〃	28 〃
1838 Great Western (first Atlantic steamer), .	236 〃	36 〃
1844 Great Britain (first ocean screw-steamer),	322 〃	51 〃
1853 Himalaya (largest screw-steamer), .	370 〃	44 〃
1856 Persia (longest paddle-steamer), .	390 〃	45 〃

The largest war-steamer now (1857) afloat, the *Duke of Wellington*, is shorter than the *Persia* by no less than 150 feet; whereas it is 9 feet broader than the broadest merchant-steamer. This illustrates the difference in qualities required for war and for mail-transit.

The Future of Ocean-steaming—the *Great Eastern*.

The *Great Eastern*, the most wonderful specimen of naval architecture yet attempted, was suggested by certain disadvantages inherent in all the steamers previously built. An adequate supply of steam has been the great desideratum; for it is owing to a deficiency in this requisite that steamers, in very long voyages, have hitherto borne all the expenses without reaping all the advantages of that mode of propulsion. A sailing-ship finds wind to fill her sails at all seasons and in all seas, with certain rare exceptions; but if a steamer has to go out of her course to procure coal for the furnaces, and if a period of twelve, or even twenty days be thus lost, the advantages of high speed become almost neutralised, and a sailing-ship of clipper build will make a long voyage almost or quite as quickly as a steamer. This has been the state of the case in respect of Australian steamers down to the present time (1857): the coal-question has been the great difficulty. When, therefore, an Eastern Steam Navigation Company was formed in 1852, the problem was discussed whether a steamer could be built large enough to carry coals for (say) 23,000 miles of steaming, to Australia and back; and whether, if so built, it could be navigated swiftly and safely over the ocean. The solution of this problem was left to Mr Brunel, who had many years before triumphantly shewn, by the planning and engineering of the *Great Western*, that a steam-voyage across the Atlantic is easily practicable. The old poetic imagery concerning waves 'mountains high' has wrought some mischief, since it has led ship-builders to cramp their own movements by fear of those waves. Prophets foretold that so long a ship as the *Great Western* would 'break her back' if perched up on a mountain-wave; not only has this been disproved, but longer ships have become more and more prevalent. It has been found that ocean-waves are much shallower and narrower than used to be supposed; and a calculation is made that a ship 600 feet long would always rest on the crests of three or four waves at least, unless in a storm of unusual severity. Mr Brunel planned that the great length of his vessel should adapt it for ordinary waves, while great strength of construction should enable it to resist exceptional dangers. The *Persia* has made fourteen and a half knots an hour; and Mr Brunel has shewn that even a small increase on this speed would shorten an Australian voyage to thirty-five days—provided there were no stoppages for coaling: indeed, he contends that sixteen knots—nearly twenty statute miles—per hour might be produced with a smaller power in proportion to tonnage than ordinary vessels have hitherto required to produce ten. Not only is the *duration* of a voyage increased, but its *cost* also, by the necessity for coaling on the way. To supply Australian steamers hitherto, coals have had to be taken from England nearly half over the globe by other ships, to form coal-depôts; insomuch that every ton, all expenses included, costs four times as much as at the English ports: this, on a consumption of 4000 or 5000 tons out and home, becomes a serious matter, and is the chief cause why Australian steaming has hitherto been unprofitable.

After mature deliberation, the company and the engineer determined to build a steamer nearly 700 feet in length, that might contain 12,000 to 14,000 tons of coal, 5000 tons of measurement goods, and 4000 passengers besides crew—a daring thought, worthy of an age of high mechanical and commercial attainments. Mr Scott Russell was selected as the builder, and a plot of ground adjacent to his works at Millwall was leased by the company as the place of building. The building-yard was prepared by piling to an immense depth, and was provided with engineering-shops, foundries, forges, rolling-mills, and all the appliances for building an iron ship. Without tracing the progress of the works year by year to 1857, it may suffice to describe briefly the ship itself, supposed to be finished.

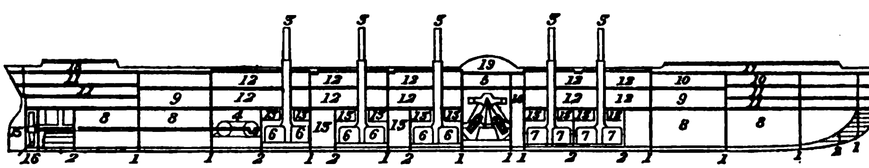
The length of the *Great Eastern** between the perpendiculars is 680 feet, and on the upper deck, 692 feet; the breadth of the hull, 83 feet; and including paddle-boxes and their fenders, 118 feet—equalling the width of Portland Place, one of the broadest streets in London, or in England; the height of the hull is 60 feet; the weight of iron in the hull is 7000 tons; the launching-weight, 10,000 tons; and the weight of the whole ship when voyaging, with every contemplated article and person on board, not less than 25,000 tons! At this full load she will draw 30 feet of water. The hull of the ship is a system of ribs or webs, 35 in number, running longitudinally from stem to stern, up to about five feet above deep-water line, and divided by vertical ribs at certain intervals, so as to present a series of oblong quadrangular openings. Into these openings are fitted two series of iron plates, three-quarters of an inch in thickness, strongly riveted to the ribs by means of angle-irons; these plates form two walls or skins to the ship, thirty-four inches asunder. Thus the double wall is a system of iron cells, presenting, like the Menai Bridge, the maximum of strength with the minimum of material. There is no external keel; the bottom is quite flat and cellular like the rest. Every one of the 10,000 or more thick iron plates used in the hull has had a particular curve given to it, to adapt it to the shape of the vessel. More than 2,000,000 rivets have been used in fastening the plates and ribs—all inserted and hammered while white hot.

The interior of the ship is thus arranged: Running crosswise are ten or twelve iron water-tight bulkheads or walls, extending the entire height to the upper deck, with no openings below the lower deck; the ship is thus cut off into ten or more compartments, generally about sixty feet long, any one of which might be filled with water up to the level of the lower deck, without flooding any of the others—a matter of great importance in the event of shipwreck. Five of the compartments near the centre of the ship form five complete hotels for passengers; each comprising upper and lower saloons, bedrooms, bar, offices, &c.; and each cut off from all the others by the iron bulkheads. It is as if five hotels, each measuring about eighty feet by sixty, and twenty-five feet high, were let down into an equal number of

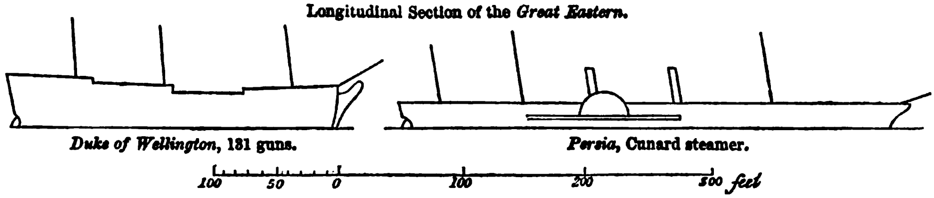
* For various drawings and details relating to the ship, we are indebted to the kindness of Mr Jacomb, assistant-engineer in its construction.

vast iron boxes. Vertical longitudinal walls separate each compartment into central saloons, and side-cabins, or bedrooms, and decks, separate the height into two series of such rooms. The arrangements are intended for 800 first-class passengers, 2000 second-class, and 1200 third-class and soldiers. The crew and engineers, 400 in number, will be accommodated near the two ends of the vessel. The upper deck is flush fore and aft, except sky-lights and ventilating openings, thus presenting a promenade nearly *an eighth of a mile* in length; it has an iron basis, double and cellular, like the hull. The arrangements are planned with an amount of room and comfort for each passenger never attempted in other ships: the upper saloons being twelve feet in height, and the lower nearly fourteen.

The means of propulsion are vast in power and unprecedented in combination, since they include the paddle, the screw, and the sail. The paddle-wheels are 56 feet in diameter, larger than the circus or arena at Astley's Amphitheatre, with float-boards about 13 feet long. They are driven by engines with four cylinders, the largest ever made on the oscillating principle; the cylinders have a diameter of 74 inches, and 14 feet stroke. These engines, standing nearly 50 feet high, were made by Messrs Scott Russell at the Millwall works. The screw-propeller, 24 feet in diameter, with four fans or vanes, and a shaft 160 feet long, and 60 tons-weight, is driven by two engines made by Messrs Watt of Soho—the largest ever made for marine purposes; they have four cylinders 84 inches in diameter, with 4 feet stroke. Each cylinder for the screw-engines was cast in a single piece, and required thirty-four tons of molten metal in the casting. The under half of the ship is divided by several iron partitions and arches, as well to strengthen the structure as to accommodate the machinery. The coals are ingeniously packed around and above the boilers, so as to be near at hand, and to shield the passengers from the heat of the boiler-rooms. There are four enormous boilers to supply steam for the paddle-engines, and six for the screw—the furnaces being so constructed as to burn either anthracite or common steam-coal. The transverse bulkheads or iron partitions, as has been already described, form impenetrable barriers between the compartments; but to facilitate the passage of workmen, pipes, &c., iron tunnels are driven through the partitions and the coal-bunkers, rendered everywhere water-tight. Sails will not be needed in the ordinary state of the weather; but to take advantage of a very brisk wind in a favourable direction, and to assist in steadying and steering, there are six masts carrying 6500 square yards of canvas. To aid the 400 sailors and engineers in working the ship, there are auxiliary steam-engines, from which power may be 'laid on' for hoisting sails, heaving anchors, pumping, &c. There will be ten anchors, 800 fathoms of chain-cable, and numerous capstans and warps. The plans include an electric telegraph to communicate orders to various parts of the ship—especially from the commander to the engineer, the look-out man, and the helmsman. Gas will be made on board, to light the various parts of the ship. In order to leave no precautions for safety unprovided, there will be boats enough



Longitudinal Section of the *Great Eastern.*

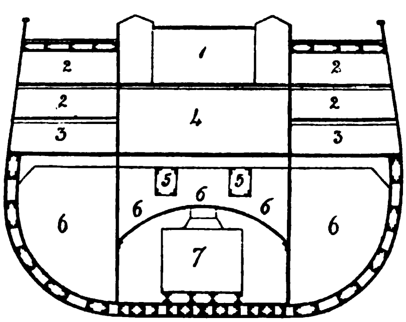


Relative lengths of the largest ships yet built, 1857.

to contain all the passengers and crew: two of them being screw-steamers 90 feet long, hung on davits abaft the paddle-boxes.

The great length of this vessel has rendered necessary the adoption of a new plan for launching. In ordinary circumstances, a ship is built on a sloping ground or slip, with a descent of about one foot in fourteen towards the water-side; but in this instance the vessel is built on a level, broadside towards the river. For launching, two timber platforms of immense strength are formed, from the ship's position to low-water mark; each platform eighty feet in width, smooth at the top, and having a slope towards the water of one in twelve, is supported by a vast substructure of piles driven into the ground. Two cradles of massive timber are built temporarily under the hull, one between the midship and the head, the other between the midship and the stern; and when all subsidiary arrangements are ready, these two cradles slide down the two platforms, carrying the monster-ship —*twenty million pounds-weight*—with them. This is done at low-water, and the rising tide floats the vast fabric.

The following references apply to the wood-engravings. In the longitudinal section of the *Great Eastern:* 1, Main transverse bulkheads; 2, Partial bulkheads beneath lower deck; 3, Funnels from the five pairs of boilers; 4, Screw-engines; 5, Paddle-engines; 6, Screw-engine boilers; 7, Paddle-engine boilers; 8, Cargo space; 9, Cargo



Midship section of *Great Eastern.*

and horse space; 10, Officers' and crew's berths; 11, Capstans, chains, anchors, &c.; 12, Passengers' saloons; 13,

Coal-bunkers; 14, Auxiliary engine-room; 15, Rudder; 16, Screw-propeller; 17, Forecastle; 18, Space for live-stock; 19, Paddle-box. The relative lengths are shewn of the *Duke of Wellington*, the longest war-ship, and the *Persia*, the longest ocean-steamer afloat previous to the launching of the *Great Eastern*, with which they are both placed in comparison by the adoption of the same scale. In the midship section: 1, Upper saloon; 2, Cabins; 3, Cabins, baths, &c.; 4, Lower saloon; 5, Tunnels; 6, Coals; 7, Boilers. This section also shews the cellular structure of the double skin round the lower part of the hull, and of the upper deck.

NAVIGATION.

Navigation is the art of conducting vessels at sea in the direction in which they are designed to proceed; the term is derived from the Latin word *navis*, a ship, and *ago*, to manage or govern. From *navis* also is derived the term *navy*, which signifies a collection of ships. The terms *marine*, *maritime*, and *mariner*, are likewise from a Latin root—namely, *mare*, the sea.

Laying aside the consideration of steam as a moving-power, vessels may be said to advance in their course by means of tides, currents, and winds; the winds are in most instances the principal agent, and the art of the mariner consists in rendering almost every breath of wind which blows subservient to the purpose of the intended voyage. The winds most favourable for impelling the vessel are those which blow on the *quarter*, or slantingly on the ship's course. The reason for this is very obvious: when the wind blows directly astern, it can affect only one or two sails with commensurate force; but when it comes obliquely, every sail may be trimmed to meet it, and receive a share of the impulsive power. The variety in the rigging of vessels causes much difference in sailing powers: some will sail close to the wind, as it is called, or with a very small angle to the direction of the breeze, while others require winds much more fair. When the wind becomes too powerful, certain sails are taken in, and others are *reefed*, a portion being bound to their respective yards, so as to reduce the surface of canvas. Reefing and bracing the yards are among the nicest points of seamanship.

Ships are navigated, as nearly as possible, by the path which is the shortest distance between the port whence they depart and that for which they are destined; but from contrary winds and intervening land, it is generally necessary to sail in a track of a zigzag form. When a vessel is obliged to sail to the right or left of the direction of the intended port, it is said to *tack;* when the ship is tacking towards the left, and the wind consequently on the right, it is said to be on the *starboard* tack; and when it is tacking towards the right, it is said to be on the *larboard* tack. A ship does not sail exactly in the direction of her keel, but deviates towards the side that is opposite to the wind; and the angle contained between the apparent and real direction is called *leeway*.

The tacking or changing of directions, in order to present the sails at a proper angle to the wind, is a process requiring considerable seamanship. The ship being already close to the wind, the helm is gradually eased *down*, so that the rudder may not exert its full force until she begins to turn, nor act suddenly to check the headway, so essential to the success of the evolution; at the same time the head-sheets are flown, so as to cause the sails before the centre of rotation to shake, and lose their power of balancing the after ones. As the ship approaches the wind, the spanker is drawn gradually from the lee-side towards the centre, that it may keep full, and by its action so near the stern, continue promoting the rotation. As soon as the sails reach the direction of the wind, and cease to draw, the corners of the courses are drawn up, and the tacks and sheets overhauled, ready to swing the yards. After a while, the sails catch aback, and the foresails, soon making the after ones, act with a powerful leverage in turning the bow. At length, having come head to wind, without loss of headway, and the evolution being certain, the after-yards are swung round, ready to receive the wind on the opposite side; which operation is then more easily performed, from the sails being becalmed by the fore ones. Lastly, when the after-sails are filled by the wind, the head-yards are also braced round to receive its impulse, and the ship at once recovers headway, and proceeds on her new tack.

Thus easily is a ship manœuvred in fine weather. Not unfrequently, however, a gale comes to disturb the peaceful course of the mariner, and call forth all his exertions. Let us suppose that, whilst our ship is contending against the head-wind, the misfortune is augmented by its gradual increase. Shortening sail becomes necessary, and is determined by two leading considerations—the stability of the ship and the strength of her masts: it is to diminish the careening of the one, and avoid endangering the other, that the surface spread to the wind is reduced. In shortening sail, we always begin with the highest and lightest sails, descending gradually, and keeping pace, in an inverse ratio, with the increase of wind. The sails do not, however, come in uniformly in the direction of the length; but the after-sails most rapidly; because, as the wind increases, the energy which it exerts in a forward direction upon the masts, tends, with a powerful lever, to depress the bow and raise the stern. Hence the latter drifts more easily to leeward, thereby bringing the bow towards the wind; this effort is also promoted by the action of the sails passing further to leeward, and by the ship ceasing to sail on an even keel. From all these reasons, the more the wind increases, the more she tends to come to; so, to avoid a constant recurrence to the action of the rudder, it becomes necessary to shorten sail faster aft than forward, taking in the mizzen-top-gallant-sail, and even the spanker, before the fore and maintop-gallant-sails: for the same reason, when it becomes necessary to reef, it is not unusual to begin with the mizzen-top-sail. In the case of a heavy gale, it is sometimes necessary to reef or take in the whole from stem to stern; the helm being at the same time kept constantly hard down, the vessel is said to *lie to*.

The Compass.

The most important instrument for the guidance of the mariner is the compass. There are different kinds of compasses, to suit peculiar purposes; but that which is commonly in use on shipboard is of the following construction:—The most essential part is a magnetised bar of steel, called the needle, which is supported horizontally on a central pivot, round which it is free to move and to point in any direction. The pivot of the needle rises from a circular *card*, resembling the dial-plate of a time-piece, and round the circumference of which are marked thirty-two points. The figure on next page represents the card of a compass. North, South, East, and West are the main or cardinal points, and are indicated by their initial letters respectively, while the subordinate points are also marked by letters—as, N*b*E, for north-by-east; NNE, north-north-east; and so on. To recite the various points is called 'boxing the compass.' The north is usually indicated by an ornamented figure, or arrow-head, as in the annexed sketch.

The card and needle are fixed in a round box, enclosed by a sheet of glass, to secure it both from the agitation of the atmosphere, as well as to exclude dust, moisture, and other things which might interfere with the correctness of the indications. The whole is enclosed in another box, suspended by two concentric brass circles or *gimbals*, as they are technically called, and in such a manner that the compass hangs as it were on points like a swivel, by which, during the lurching, or heaving up and down,

or motion from side to side of the ship, the needle and its card remain in a horizontal position, and under all

circumstances indicate the various points correctly. The compass, thus incased, is placed upon deck in a covered stand, called the *binnacle*, in front of the man at the helm, so that the direction in which the needle points can be constantly seen in guiding the vessel. The point of the needle—which, for distinction, is some way ornamented—is understood to point towards the north, but it is only at very few places on the earth's surface that it points due north. It has almost everywhere a *variation* or *declination*, either to the east or to the west of north; and this, as well as other variations to which it is subject in certain latitudes, must be thoroughly understood by the navigator. (See ELECTRICITY—MAGNETISM).

The needle being liable to be affected by the proximity of iron, no piece of that metal is used in the construction of the binnacle, or is allowed to be near it. In the case of iron ships, or ships having much iron on board, means are adopted to counteract the tendency which the needle has to point in a wrong direction; but the subject is attended with difficulty, and is still undergoing investigation. The most effectual way, it seems, yet found of guarding the compass from the deranging effects of the metal in the ship, is to place it high above the deck.

The Log—Sextant.

Provided with a compass, the next object of importance is the *log*, an instrument for measuring the rate at which the vessel proceeds through the water in a given space of time. The log is a very simple contrivance. It consists of a long cord, having a piece of wood attached to one end, and called the *chip*. This is of a quadrantal form, and being slung at the corners with line, and loaded at the circumference, when thrown overboard it remains erect and stationary, and drags the line off as fast as the ship passes through the water. The line is divided into knots and half-knots, representing miles and half-miles, or minutes of a degree, to which they bear the same proportion as the log-glass does to an hour. Thus, the log-glass being filled with sand to run through in 30″, the length of a knot must be 51 feet, the first being the same proportion of an hour that the last is of a mile. As, however, the log is found to come home a little in the effort to draw the line out, it is customary to mark the knot a foot or two less than the true length. The mode of heaving the log to measure a ship's rate is as follows: The log-reel, upon which the line is wound, being held by one of the sailors, the officer places himself on the rail to leeward, and a third person holding the glass, he proceeds to prepare the chip, so that the peg of one of the lines holding the chip in a perpendicular direction will draw out, by the force of the water, when the reel is stopped, and allow it to haul in easily. Then having gathered a sufficient quantity of line into his hand, he throws it far to leeward, that it may not be affected by the eddies which follow in the wake. The stray line, which allows the chip to get astern, now runs off, and the instant that the white rag, which marks its termination, passes through the hand of the officer, he cries 'Turn!' and continues to veer out line until the glass runs out, and the person holding it cries 'Stop!' Then the line is grasped, and the number of knots that have passed off mark the speed of the ship. When this exceeds five miles, it is usual to use a glass of 15″ instead of 30″, counting the knots double. The rate of sailing per hour multiplied by the hours sailed, thus gives the mariner the measure of his run.

In addition to these essential instruments for directing the course and ascertaining the distance, the navigator must be provided with *octants* of double reflection, to measure the altitude of the heavenly bodies, and a circle, or *sextant*, more nicely graduated, to measure distances between the moon and stars. He should also have with him a book containing the logarithms of numbers, sines, tangents, and secants, to facilitate trigonometrical calculations; tables for correcting altitudes for dip, parallax, and refraction; also lists of latitudes and longitudes for every part of the world; and of time of high-water at every port, at the period of full and change of the moon, from which at all times to be able to find the tide; and a variety of tables to facilitate the various problems of navigation. He should also have with him the *Nautical Almanac*, containing the places and declinations of the fixed stars and planets, and especially the distances of the moon from the sun and other stars, and all that relates to that body, with a view to calculate the longitude by observation. Finally, he must be provided with the general and local charts applicable to his contemplated voyage.

Thus furnished, the mariner may set sail with confidence; many do so with no other aids than their compass, log, quadrant, a single chart, and book of navigation, and arrive in safety. But it is less our business to shew with how little care a ship may be navigated, than to shew how she may be carried from port to port with the greatest possible certainty. Having taken leave of the port, and when the last land is about to disappear from view, either from the growing distance or the intervention of night, the mariner selects some conspicuous headland, of which the latitude and longitude are noted in his tables, and placing a compass in some elevated position, remote from any iron object to disturb its polarity, proceeds to determine its bearing, and estimate his distance from it, either by the progress made from it, or by the ready estimate of a practised eye. Or taking the simultaneous bearings of two distinct points of coast, he has still surer data for deducing his position. This is called *taking the departure*, and is carefully noted on the log-slate, with the time of making the observation. Thenceforth the log is thrown every hour, and the course and distance are entered upon the slate, to be copied into the log-book at the end of the day.

Working a Reckoning.

At the first noon succeeding the time of taking his departure, the mariner works up his reckoning. Noon is an epoch fixed by nature, being determined by the passage of the sun over the meridian, and is therefore well chosen as the beginning of the day. The log-slate being marked, he copies the courses and distances, if from head-winds or other causes, they have been various; the departure from the land is also converted into a course; as is also the current, if there be any known one. He next proceeds to find the difference of latitude and departure from the meridian corresponding to each course, either by geometrical calculation, or more expeditiously, by reference to tables; then he adds the several differences of latitude and departure, and if they be of different names, as some north and some south, some east and others west, deducts the less from the greater. With the remaining difference of latitude and departure, he not only finds the course and distance made good, but

also the latitude and longitude in which he is; the difference of latitude being applied to the latitude left, by adding or subtracting, in sailing from or towards the equator, at once gives the latitude of the ship. But before the departure can be thus applied to find the longitude, it is necessary to reduce it for the converging of the meridians towards the poles; for though all degrees of longitude are divided, like those of latitude, into sixty minutes or miles, yet they decrease in length from being equal to a degree of latitude at the equator, until they become nothing at the poles. There are many ways, more or less accurate, of deducing the difference of longitude from the departure, the latitude being known; they are founded upon this principle: the circumference of the earth at the equator is to its circumference at any given parallel of latitude as the departure is to the difference of longitude. The most easy and correct way of obtaining the difference of longitude on an oblique course, is by the aid of a table of meridional parts; for having taken out the meridional difference of latitude, the mariner has this simple proportion—the proper difference of latitude is to the meridional difference of latitude as the departure to the difference of longitude. The difference of longitude thus obtained is applied to the longitude left, adding or subtracting in sailing to or from the first meridian, and the result will be the ship's longitude; which, with the latitude previously ascertained, determines her position on the chart. The method of navigating thus described is called *dead reckoning.* It is far from infallible, and leaves much to desire. It will indeed do pretty well in short runs; but as errors daily creep in from any causes escaping calculation, such as bad steerage, leeway, heave of the sea, unknown currents; and as these accumulate, and become considerable at the end of a long voyage, it becomes necessary for the mariner, removed from all reference to terrestrial objects, to resort to the immovable guides in the heavens. All the heavenly bodies are, by the revolution of the earth, daily brought to the meridian, at which time, if their altitude is measured, their declination or distance from the equinox being known, the latitude is readily deduced; it may also be deduced from single or double altitudes of bodies not in the meridian, the times being accurately known. But the meridian altitude of the sun is what furnishes at once the easiest and most correct method of finding the latitude.

Taking an Observation.

Furnished with a sextant, circle, or octant of reflection, the observer goes upon deck, and having examined the adjustment of his instrument, proceeds to bring down the image of the sun reflected by its mirror, until the lower limb just sweeps the horizon. He continues to follow and measure its ascent, until it ceases to rise; the moment that it begins to fall, and the lower limb dips in the horizon, the sun has passed the meridian. The altitude marked by the index being read off, it is next corrected. And first, the observer adds the semi-diameter, in order to make the altitude apply to the centre of the object; next he subtracts the dip, to meet the error caused by the extension of the horizon, in consequence of the rotundity of the earth, and the elevation of his eye above its surface; also the refraction of the atmosphere, by which the object, when not vertical, is made to appear higher than its true place; lastly, he adds the parallax—a small correction inconsiderable from the sun's distance—in order to reduce the calculation for the centre of the earth; from which point all calculations are made, and which is ever supposed to be the station of an observer.

Having made all these corrections, which many mariners despatch summarily, by an addition of twelve minutes, he has the true meridian altitude of the sun. Taking this from a quadrant, or ninety degrees, gives its zenith distance, or distance from that point in the heavens which is immediately over the observer, and would be met by a straight line passing from the centre of the earth through his position. Now, if the sun were for ever on the equinoctial, the zenith distance would always be the latitude; for whilst the zenith is the observer's position, referred to the heavens, the equator is there, in like manner, represented by the equinoctial; and we have already seen that latitude is the distance from the equator. But as the sun is only twice a year upon the equinoctial, and as his distance from it at times increases to more than twenty degrees, it becomes necessary to take this distance—called his *declination*—into the estimate. The sun's declination is given in the Almanac for the noon of each day; by correcting it for the time anticipated or elapsed, according as the sun comes first to him or to the first meridian, by his position east or west of east of it, the observer obtains the declination for noon at his own position. This declination applied to the zenith distance, by adding when the sun is on the same side of the equator, by subtracting when on the opposite side, gives the true latitude.

A daily and accurate knowledge of his latitude is, then, to the mariner of modern times, a desideratum of comparatively easy attainment. By its aid, nothing is easier than to sail clear of any rock or shoal that crosses his track, either by a watchful look-out at the moment of passing its latitude, or else by avoiding its parallel entirely, until it be surely passed. Moreover, this is his best and surest guide in aiming at his destined port; for he has but to attain the exact latitude it lies in, and then sail directly upon it, east or west, to be sure of success. And here nature is again his friend: by a singular coincidence, discoverable in glancing at the map of the world, most coasts and continents lie in a northern and southern direction. Hence the value attached by seamen to an accurate knowledge of the latitude; and hence the familiar saying of 'Latitude, lead, and look-out.'

To find the Longitude.

Various ways have been devised to find the longitude, in all of which the great element is time. The earth performs her diurnal revolution in twenty-four hours, or, in other words, each part of the circumference of the globe, which is divided into 360 degrees, is brought under the sun once a day. Hence each part of the circumference—reckoning from east to west—has its own peculiar time of day. When it is noon at one place, it is one o'clock afternoon at another place, two at another, and so on; the time differs all round the globe. Dividing the 360 degrees by 24, we find that 15 is the result; for every 15 degrees, therefore, along the circumference going westward, there is an hour of difference, in advance; and going eastward, an hour behind. If it be noon at Greenwich, it will be one o'clock at a point 15 degrees east from it—that is, the sun has passed over it an hour ago—and eleven o'clock forenoon at a point 15 degrees west from it—that is, the sun will be an hour in getting up to it. Dividing the 60 minutes of an hour by 15, the result is 4; the earth, therefore, moves under the sun at the rate of a degree, or sixty geographical miles, in four minutes, or fifteen miles in the minute, or one mile in the four seconds, or a quarter of a mile in the second. Here, then, the element of time is brought at once, and in the most satisfactory manner, to bear upon the distance of any given place, east or west from any other given place. The measuring of such a distance is called finding the longitude.

Different places on the globe have been established as starting-points in making these measurements. The French reckon from Paris, and the English from Greenwich, near London, where an astronomical observatory has been long established, and supported at the public expense. In all English works of geography, the longitude is reckoned from Greenwich, although not expressly mentioned. Navigators determine their longitude by watches or chronometers, whose movements are as exact as can possibly be obtained from mechanism. (See

HOROLOGY.) In setting out on a voyage, the chronometer is set to Greenwich time, and kept going at that time. At the hour of noon of each day, as determined by an observation with the sextant, the difference is estimated between that hour and the hour indicated by the chronometer, and that difference is the longitude east or west of Greenwich, as the case may be. Some mariners, for security, take several chronometers to sea with them, as one only is by no means a safe guide. In general, however, the masters of coasting-traders, or those who pursue short voyages by regular lines of route, depend on books containing lists of longitudes as well as of latitudes.

Marine Barometers—Log-book.

The last great requisite in navigation is a good barometer, to indicate the approach of foul weather. The most delicate instrument of this kind is the sympiesometer of Adie, by which the earliest and most certain indications are presented of coming storms. In treating of the nature and value of instruments of this kind, Dr Arnott makes the following observations: 'The watchful captain of the present day, trusting to this extraordinary monitor, is frequently enabled to take in sail, and to make ready for the storm, when in former times the dreadful visitation would have fallen upon him unprepared. The marine barometer has not been in general use for many years, and the author was one of a numerous crew who probably owed their preservation to its almost miraculous warning. It was in a southern latitude. The sun had just set with placid appearance, closing a beautiful afternoon; and the usual mirth of the evening-watch was proceeding, when the captain's order came to prepare with all haste for a storm. The barometer had begun to fall with appalling rapidity. As yet, the oldest sailors had not perceived even a threatening in the sky, and were surprised at the extent and hurry of the preparations; but the required measures were not completed, when a more awful hurricane burst upon them than the most experienced had ever braved. Nothing could withstand it; the sails, already furled and closely bound to the yards, were riven away in tatters; even the bare yards and masts were in great part disabled; and at one time the whole rigging had nearly fallen by the board. Such, for a few hours, was the mingled roar of the hurricane above, of the waves around, and of the incessant peals of thunder, that no human voice could be heard, and amidst the general consternation even the trumpet sounded in vain. In that awful night, but for the little tube of mercury which had given the warning, neither the strength of the noble ship nor the skill of the commander could have saved one man to tell the tale.'

A journal of events and observations on board ship is usually kept in what is called the log-board, and transferred thence into the log-book. The log-board consists of two boards shutting together like a book, and divided into several columns, containing the hours of the day and night, the direction of the winds, and the course of the ship, with all the material occurrences that happen during the twenty-four hours, or from noon to noon, together with the latitude of observation. From this table, which is written in chalk, and daily effaced, the officers work the ship's way, and compile their journals. From it, also, entries are carried to the log-book in an expanded form, with any observations and additional particulars supposed to be necessary. The log-book is thus the journal of the ship, and is preserved with great care for exhibition, if required, at the termination of the voyage.

LIGHT-HOUSES—BEACONS.

Beacons, warning-bells, light-houses, and the like, are among the most indispensable adjuncts of maritime conveyance; without them, indeed, it would be utterly impossible to conduct it with anything like regularity or safety. The most ancient structure of this description which we read of was the Tower of Pharos—regarded by our ancestors as one of the seven wonders. It was commenced by Ptolemy the Elder, and finished some years after by himself and his son Ptolemy Philadelphus, in the year of the world 3670, on the island of Pharos, in the Bay of Alexandria. 'It was built,' says an ancient authority, 'on the east end of this island, upon a rock of white marble, of a large square structure, on the top of which fires were kept constantly burning for the direction of vessels. It was a most magnificent tower, 450 feet high, consisting of several stories and galleries, with a lantern at top, which could be seen many leagues at sea.' This wonderful work has been demolished for ages; as also the Colossus of Rhodes, another ancient erection of a similar nature. The Light-tower of Cordouan, in France, situated upon a low rock about three miles from land, at the mouth of the Garonne, was for a long time regarded as one of the chief wonders of modern Europe. It was founded in 1584, and completed in 1610. Its lower part consists of a solid platform of masonry, 135 feet in diameter; above which, in succession, are a number of apartments, all narrowing in circumference till the upper story is reached—being in all 145 feet high.

In our own day, the most celebrated light-house is that built on the Eddystone rocks—a low reef situated south-south-west from the middle of Plymouth Sound, nearly fourteen miles distant from that port, and about ten from the promontory of Ramhead. The reef, which stretches across the Channel for upwards of 200 yards, slopes gradually towards the south to the distance of a mile, so that the swell sweeps up, as it were, an incline, till within a few fathoms of the exposed rock, where, striking against a sudden ledge, it breaks and dashes upwards to a height of forty or fifty feet. On this dangerous reef, the necessity of a light-house was early felt; and accordingly, in 1696, a gentleman of the name of Winstanley was furnished with the necessary powers to carry such a design into execution. He entered upon his task in 1696, and completed it in four years. So certain was Winstanley of the stability of his wooden structure, that he declared it to be his wish to be in it 'during the greatest storm that ever blew under the face of heaven;' a wish that was but too soon and fatally gratified, for in November 1703, while there with some workmen and the light-keepers, a storm of unparalleled violence arose, and in one night the whole fabric was swept away. In 1709, another light-house was built of wood by a Mr Rudyerd; and this structure, after braving the elements for forty-six years, was burned down in 1755. On the destruction of this light-house, Mr Smeaton, the celebrated engineer, was next applied to, who at once fixed upon the more durable material, stone, and chose for his model the natural figure of the trunk or bole of a large spreading oak. With these views as to the proper form of the superstructure, Mr Smeaton began the work on the 2d of April 1757, and finished it on the 4th of August 1759. The rock, which slopes towards the south-west, is cut into horizontal steps, into which are dovetailed and united, by a strong cement, Portland stone and granite. The whole, to the height of thirty-five feet from the foundation, is a solid of stones, ingrafted into each other, and united by every means of additional strength. The building has four rooms, one over the other, and at the top, a gallery and lantern. It is nearly eighty feet high; and since its completion, has been assaulted by the fury of the elements without suffering any appreciable injury.

Equally remarkable with the light-house of the Eddystone is that of the Bell-rock—a sunken reef, lying at the distance of eleven miles from the promontory called the Red Head, in Forfarshire, and on the highway to the Firths of Forth and Tay, two of the most frequented estuaries in the kingdom. The ledge is said

to be about 850 yards in length, and 110 in breadth; at low-water, some of its summits appear from four to

eight feet above the level of the sea; but at high-water, they are always covered to the depth of ten or twelve feet. Tradition says that the abbots of the monastery of Aberbrothock succeeded in fixing a bell, which was rung by the swell of the sea, so as to warn the mariner of his situation; but that this benevolent erection was destroyed by a Dutch pirate, who, to complete the story, was afterwards lost upon the rock with his vessel and crew. However this may have been, it was not till the beginning of the present century that a solid substantial light-house, after the model of the Eddystone, was determined upon and erected. This work was intrusted to Mr Stevenson, the Scottish engineer; was begun in 1808, and completed in 1810. Being lower in the water than any rock on which a similar building has been raised, the difficulties of the architect were greatly increased; but by preparing all the stones on shore, and conveying them in lighters to the reef, where a tender and other accommodation were provided for the workmen, his success was complete, and the revolving ruddy light of the Bell-rock now ranks among the chief achievements of British engineering. 'The light-house'—we quote the *Edinburgh Encyclopædia*—'is a circular building, measuring forty-two feet in diameter at the base, and thirteen feet in diameter at the top. The masonry is 100 feet in height, and, including the light-room, it is 115 feet. The ascent from the rock to the top of the solid, or lowest thirty feet, is by means of a kind of trap-ladder; the ascent from the level of the entrance-door is by means of a circular stair to the first apartment, containing the water, fuel, &c.; and from thence to the several apartments the communication is by wooden steps. The windows have all double sash-frames, glazed with plate-glass, besides a storm-shutter of timber for the defence of the glass against the sprays of the sea; for although the light-room is about eighty-eight feet above the medium level of the tide, and is defended by a projecting cornice or balcony, with a cast-iron rail, formed like the meshes in net-work, yet the sprays of the sea occasionally lash or fall upon the glass of the light-room, so that it becomes necessary in gales of wind to shut the whole of the dead-lights to the windward.'

Not less bold and hazardous, in point of erection, is the recent structure on the Skerryvore—a cluster of rocks just appearing above high-water in the Atlantic, between the north of Ireland and the Hebrides, from the nearest point of which it is twelve miles distant. This light-house, commenced in 1835, and finished in 1844, by Mr Alan Stevenson, son of Mr Stevenson above mentioned, consists of a tower 138 feet high, curving inwards from a basis of forty-two feet, and contains nine apartments over each other, for the accommodation of the establishment by which the light is to be maintained. The lantern consists of an apparatus of eight annular lenses revolving round a lamp of four concentric wicks, and producing a bright blaze every minute, visible to the distance of eighteen miles. The cost of the entire structure amounted, we understand, to £89,000. We particularise this and the preceding cases as illustrations of the magnitude of some of our light-houses, and of the hazard and expense encountered in their erection—difficulties which could be surmounted only at a period of great material wealth and scientific skill, and when the importance of maritime conveyance is so vast as to compel such protection.

A number of improvements have recently been made and promulgated in the construction of light-houses, chiefly with a view to the saving of time and expense in their erection. The first deserving of notice is the iron light-house of Captain Brown. This structure is composed solely of rings of cast iron, joined or cased one upon another till the requisite height be attained. The advantages of this plan are, cheapness, facility of erection, strength, and durability. Metal light-houses—that is, composed either of cast iron, wrought iron, or gun-metal—have been strenuously advocated by Mr Gordon, who, from pretty obvious data, maintains that the Skerryvore, for example, could have been erected on this principle, with equal efficiency, at little more than one-third of its actual cost. The 'screw-pile' of Mr Mitchell is another invention likely to come into use in the erection of light-houses on shoals and sand-banks. As the name implies, the basis consists of a framework of piles screwed, instead of driven home, and on this an open fabric is erected for the support of the lighting apparatus—the open structure offering no resistance to the waves. Another set of inventors have directed their attention to the improvement of the lighting apparatus—its lamps, lenses, and reflectors. As this department involves mathematical and optical principles of high consideration, we shall merely remark, that at present the lights on our coasts generally consist of Argand burners, placed in the foci of parabolic reflectors made of silver strengthened with copper. The reflectors are arranged, and the lights exhibited, in such a manner that those on the same line of coast should have some essential distinction; thus, some of them are revolving or intermittent, many are fixed, others are placed one above another, some flash every five seconds, and not a few alternately red and white. These movements are in general effected by clock-work of a very ingenious description.

The light-houses on and about the British coasts are upwards of 200 in number, and are classed as 'harbour lights' and 'general lights.' Almost all of them are now vested in public boards, as are also the marine beacons and buoys of the kingdom. The chief board of supervision and control is the Trinity House, Deptford, incorporated so early as 1515 by Henry VIII. In Scotland, the lights are under the immediate management of the 'Commissioners for Northern Lights;' those of Ireland are under a similar trust; but both Scotch and Irish are vested in the Trinity corporation. For the erection and maintenance of lights, beacons, and buoys, a rate is levied on all vessels passing them within certain limits.*

Beacons are generally placed on sand-banks, rocks, and shoals, and are either floating or stationary. When floating, they are termed buoys (already noticed); when fixed, they are either of solid masonry, or of an open framework of wood or iron. Of late, their number has

* By an act passed in 1853, the whole affairs of the trusts are placed under the control of the Board of Trade, and brought under the review of parliament.

been much increased along the British coasts; many of them being composed of cast-iron pillars, screwed and riveted together into a substantial framework, which stands thirty or forty feet above water-level, and which no storm can possibly destroy. The most remarkable of our beacons are those erected by the Trinity House—under the superintendence of Captain Bullock—on the fatal and shifting sands of Goodwin. From the number of shipwrecks constantly occurring on these shoals, these beacons are intended to serve also as a place of refuge for shipwrecked sailors. The first and largest consists of a strong framework, sunk to a considerable depth in the sands, from which rises a vertical column; and on this, at a height of eighteen feet above high-water, is placed an octagonal platform, capable of holding forty persons. The platform always contains a barrel of water, a flag ready to be hoisted, and is inscribed in eight different languages with the words 'Hoist the flag.' The second, which was erected in 1847, is of a different construction: the centre column is a tube of cast iron two feet six inches in diameter, put together in ten and twenty feet lengths; it is inserted thirty-two feet into the sand by means of Dr Potts's newly invented process of atmospheric pressure; the four surrounding tubes are of fifteen inches diameter; the whole is bolted together, and surmounted by a cage of seven feet diameter, the top of which is fifty-six feet above sand-level.*

The great defect of beacons is, that they are not visible in dark nights, when most required for the safety of the mariner. Mr Thomas Stevenson has introduced, with great success, a mode of illuminating beacons erected on rocks or shoals situated in narrow entrances to roadsteads or harbours, where it is of the utmost consequence that the exact position of these impediments should be distinguished, but upon which it is not expedient or possible to erect a light-house. This is managed by what he terms an *apparent light*, which is produced by placing a bright reflecting apparatus on the top of the beacons, to which is transmitted, from a lamp placed in the light-house on shore, a beam of light, which is dispersed by the apparatus in the required direction, producing all the useful results of a light-house; in short, it shines by *borrowed light*.

Shipwrecks—Life-preservers.

Notwithstanding every precaution of light-house and beacon, shipwrecks are continually occurring at different parts of our coasts, and to save the lives of the seamen in such cases—without reference to the fate of the vessel—has ever been a subject of earnest consideration with the humane and ingenious. During last century, several *life-boats* were invented; among others, one by Mr Lukin in 1785. But an accident which occurred on the Herd Sands of South Shields in September 1789, led to material improvements in the art of constructing these vessels. The *Adventure*, a merchant-ship of considerable bulk, was wrecked within 300 yards of the shore, in presence of an immense number of spectators; and almost every man of the unhappy crew perished, without the possibility of receiving assistance from the shore. The consequence was, that the people of South Shields met soon afterwards, and offered a reward to any one who should invent a boat capable of being launched from the shore to the aid of ships in distress. Mr Greathead gained the premium; and in 1790, a life-boat, constructed upon the plan proposed by him, was effectually used in saving the crew of a vessel stranded under circumstances similar to those of the *Adventure*. Several other trials of the life-boat proved its utility so fully, that in 1802 the Society of Arts presented the inventor with their gold medal and 50 guineas; and parliament also decreed to Mr Greathead a reward of £1200.

* Since the above was written, storms and shipwrecks, early in 1857, have destroyed the Goodwin beacons.

The Trinity House followed the example; and the Committee of Lloyd's devoted £2000 to the purpose of building boats on the same principle.

Mr Greathead's boat was well adapted for the service of the coast on which it was introduced, and is still, with some important modifications, used there; but as it was evidently incapable of service on coasts of a different nature, other forms have been introduced to meet the various exigencies of our coast-shipwrecks. The life-boat service is now divided into two branches: 'ships' life-boats'—to provide a communication from the wrecked ship itself and the shore—and what may be called 'shore life-boats,' to communicate from the shore to the ship. The latter department, which we shall consider first, received a great impulse from the prize of 100 guineas, which the Duke of Northumberland offered, in 1851, for the best model of a life-boat. To compete for this, 280 models and plans were sent to the surveyor's department of the Admiralty, to be reported upon. Captain Washington and a board of examiners went into the whole matter most thoroughly, and issued a report, in which they named fifteen points which they considered essential to be attended to in the construction of a life-boat. The prize was given to Mr Beeching of Great Yarmouth. The principal feature of this boat was the fitting of a water-ballast tank, which for a twenty-eight feet boat would contain a ton of water, and which extended three-fifths of the breadth midships, and three-sevenths of the length; the spaces left at the sides and ends being filled with air-bladders. This prize-boat has been supplied to several stations, but its success has not been so marked as was anticipated. The 'Northumberland Committee' appointed Mr James Peake, naval architect at Woolwich Dockyard, to prepare drawings of a life-boat in which all the best features of the models were combined. The same gentleman has succeeded in introducing since then a life-boat, which, by eminent authorities, is said to be very efficient as a coast life-boat. This boat is four times as long as she is broad, with a flat floor and straight sides, with considerable curvature in the direction of its length. A water-tight platform or deck is provided; the bilge-spaces are filled with blocks of light pine, instead of cork or air boxes. In the midship part of the platform, a covered well is made for holding cable, anchor, and stores. Air-boxes are provided at the sides under the thwarts, and air-compartments in the bow and stern, as high as the gunwale; these give the self-righting power to the boat, which is also aided by a thick iron false keel, bolted to the keel bottom and kelson. The boat frees itself of water by tubes passing through the bottom, and provided with self-acting relieving-valves at the height of the platform. The boat steers with oars, and is fitted to carry a small lug-sail, and is amply provided with life-buoys and every requisite for coast-service.

A form of life-boat known as the 'tubular' has been introduced by Mr Richardson; it has been severely tested, and is pronounced a thoroughly efficient boat, by first authority. It is formed of two tubes of tinned iron, forty feet long, two and a half in diameter, and tapering at either end. An iron frame unites the whole into one mass. The tubes are divided into water-tight compartments filled with air-proof bags. A life-boat on the raft-principle was introduced in 1855 by Mr Severn of the Royal Mint, Australia. The principle consists in dividing a whale-boat longitudinally, giving flat sides to each half, and keeping the two separate some eight or ten feet by strong diagonal bracing. The rowers sit above air-cases and water-ballast tanks, which are placed at the sides.

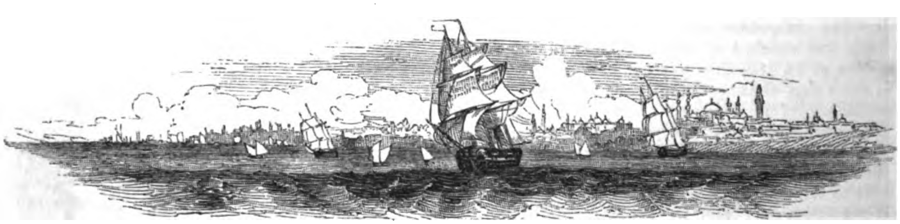
Notwithstanding all the improvements, life-boats are still not proof against heavy storms. In January 1857, the life-boatmen of Rhyl, in Wales, bravely put off to aid a distressed ship; but their boat, although of the most approved construction, was overturned, and all hands lost.

We have now to direct brief attention to the department of ships' life-boats. This is scarcely less important than that of coast-boats. George Palmer, Esq., late M.P. for Essex, was the first to introduce a boat for this purpose. It was built as a whale-boat, sharp at both ends; buoyancy being obtained by air-casks and cases in the wings, bow, and stern, under the thwarts. Mr A. Henderson, a civil engineer, who has devoted much of his attention to life-boats, has introduced a method of applying the life-boat principle to ship-boats, as ordinarily in use. The buoyancy is obtained by 'side-compartments between a rising plank, fore and aft under the thwarts, ... and a fore and aft platform over the bulkhead at the bilge; the bow and stern partitions to be made up by a side-plank; .... between midship thwarts to be filled by six air-casks or water-breakers, the bilge below platform to be filled with cork.' The 'collapsing boats,' invented by the Rev. J. S. Berthon of Fareham, are particularly useful on board ship, to act as life-boats on emergencies; when folded up, they occupy a space of only one-sixth of their width when open. They are stowed outside the ship's bulwarks with strappings. When the boat is allowed to fall with its weight upon slings attached to its gunwale, it opens instantaneously without any manual labour, and is kept permanently open. The framework is of wood, with fastenings of metal, and is formed of longitudinal timbers running the whole length; they are hinged to each other, and to the top of the stern and stern-post. When opened, they extend two skins of a strong water-tight material; the outer skin being attached to the outer edges of the timbers, and the inner to the inner edges. A number of water-tight compartments are thus formed, corresponding in number to the air-spaces between the timbers; these air-cells expand and become filled with air as the boat opens.

Next in importance to having an efficient ship's life-boat, is that of a plan by which it can be readily and safely lowered from the ship's side. Want of good plans to attain this has frequently led to lamentable loss of life. The sad tragedy of the burning of the steam-ship *Amazon*, and the loss of life occasioned by this deficiency, gave a great impulse to invention in this department. The plan best known, and said to be the most efficient for lowering ships' boats, is that of Lacon's, which was a result of this impulse. The principal feature is the employment of a friction-brake, by which one man can regulate the rate of descent to any degree of speed. Although highly recommended by first-rate authorities, it is unfortunate that the cost of erecting the apparatus is such as to exclude its being used generally. The plan adopted by whalers consists in strong davits, a good purchase of two large threefold blocks with swivel hooks into a shackle at the top of the stern and stern-post.

Captain Manby's Apparatus.—Next to the life-boat, the most important inventions for the humane end of saving lives at sea have been those of Captain Manby, which have for their object *the throwing of a rope from the shore to the ship, or from the ship to the shore.* Boats with the crews could obviously be thus drawn ashore in almost any circumstances. A cannon-shot affixed to a rope, and projected from a piece of ordnance over a stranded vessel, seemed a practicable mode of establishing the communication. Simple as the idea was, many difficulties were in the way, and were only removed by patient and long-continued trials. These resulted, however, in crowning the inventor's efforts with complete success, affording him the great gratification of knowing that his plans were useful in saving many lives. The original plan of throwing a rope from the shore to the stranded vessel, then to be seized by the crew, was obviously capable of great improvement. The first point to be attended to was a means of attaching the rope to the ship without the intervention of the crew, who might be incapable of affording assistance through cold or fatigue. This was effected by having a quadruple barb attached to the shot, which fastened to the rigging, and by means of which a boat could be hauled from the shore to the ship. The third point was to enable the position of the vessel to be accurately ascertained in the dark; this being attained by throwing up a fire-ball filled with stars, which, on the ball bursting, took fire, and threw out a great light.

Floats and Life-buoys are also useful on board ship. The floating life-buoy invented by Lieutenant Cook of Plymouth is in common use. It consists of two casks connected by a bar between them. The buoy is suspended to the stern of the vessel by a chain; a trigger ignites a port-fire previous to being lowered into the water; the light thus afforded is a guide at once to the person who has fallen overboard, and to the boat sent out in search of him. Since the introduction of air-tight and waterproof materials, a great variety of floats have been introduced; these are in the form of belts, mattresses, capes, waistcoats, and are capable of being immediately filled with air, which gives them buoyancy. Cork, in a variety of shapes and methods of manufacture, is also used as a material for floats.



ARCHITECTURE.

ARCHITECTURE, or the art of planning and raising edifices, appears to have been among the earliest of human inventions. The first habitations of men were such as nature afforded, with but little labour on the part of the occupant, yet sufficient to supply his simple wants—grottos, huts, and tents. In early times, the country of Judea, which is mountainous and rocky, offered cavernous retreats to the inhabitants, who accordingly used them instead of artificial places of shelter. From various passages in Scripture, it appears that these caves were often of great extent, for in the sides of the mountain of Engedi, David and 600 men concealed themselves. In the course of time, art was employed to fashion the rude cavernous retreats, and to excavate blocks by which rude buildings were composed in more convenient situations. The progress of architecture, however, from its first dawn, differed in almost every different locality. Whatever rude structure the climate and materials of any country obliged its early inhabitants to adopt for their temporary shelter, the same structure, with all its prominent features, was afterwards kept up by their refined and opulent posterity.

After mankind had learned to build houses, they commenced the erection of temples to their gods, and these they made still more splendid than private dwellings. Thus architecture became a fine art, which was first displayed on the temples, afterwards on the habitations of princes and public buildings, and at last became a universal want in society.

Traces of these eras of advancement in the art of erecting buildings are found in various quarters of the globe, especially in Eastern countries, where the remains of edifices are discovered of which fable and poetry can alone give any account. The most remarkable of these vestiges of a primitive architecture are certain pieces of masonry found in Greece, Asia Minor, and in the island of Sicily, called the works of the Cyclops, an ancient and fabulous race of giants, mentioned by Homer in his *Odyssey*. By whom these gigantic walls were actually erected, is unknown, though it is most probable that they were raised by the Pelasgians—the predecessors or ancestors of the later Greeks. A gradual progress, indeed, may be traced in them, from the extreme of rudeness, to a degree of symmetry that indicates an approach to the elegance of Grecian architecture. Mr Hamilton divides these so-called Cyclopean structures into four eras:—1. Those such as the walls at Tyrins and Mycene, in which the blocks are of various sizes, having smaller stones in their interstices; 2. Those at Julis and Delphi, formed of irregular stones, without courses, their sides fitting to each other; 3. Where the stones are in courses of the same height, but of unequal length, as in Bœotia, Argolis, and Phocis; 4. Where the blocks are of various heights, and always rectangular, as in Attica.

Of the progressive steps from comparative rudeness to elegance of design, history affords no certain account, and we are often left to gather facts from merely casual notices. The most ancient nations known to us, among whom architecture had made some progress, were the Babylonians, whose most celebrated buildings were the temple of Belus, the palace and the hanging-gardens of Semiramis; the Assyrians, whose capital, Nineveh, was rich in splendid buildings; the Phœnicians, whose cities, Sidon, Tyre, Aradus, and Sarepta, were adorned with equal magnificence; the Israelites, whose temple was considered as a wonder of architecture; the Syrians; and the Philistines.

Of the peculiarities of the styles adopted by those nations, we have no definite information, with the exception of that of the Assyrians at Nineveh. The researches of recent travellers, as Layard and Botta, have enabled us to form a clear notion of the characteristics of this interesting era of the art. A notice of these the reader will find in its proper place in the present paper.

To the researches of Mr Robert Fergusson, we are indebted for works illustrative of the peculiarities of Indian architecture, and for a series of beautiful illustrations of the caves in the islands of Elephanta and Salsette, near Bombay, and of the rock-cut temples in the mountains of Ellora, near Aurungabad. These temples may be reckoned among the most stupendous ever executed by man. The circuit of the excavations is about six miles. The temples are 100 feet high, 145 feet long, and 62 feet wide. They contain thousands of figures, appearing, from the style of their sculpture, to be of ancient Hindoo origin. Everything about them, in fact, indicates the most persevering industry in executing one of the boldest plans. In the chief temple, the vault is supported by several rows of columns, which form three galleries, one above the other. Twenty-four colossal monoliths, representing Indian gods, are placed in separate divisions, the sculpture of which, though on the whole rude, shews in some parts an advanced period of art, and a certain development of taste. In many respects, Hindoo architecture bears a striking resemblance to the Egyptian (hereafter described), more especially in the pyramidal character of its masses, in its excavations and cavern-temples, as well as those which, though presenting the forms of constructed buildings, are yet hollowed out of the rock. The Egyptian, however, is more simple and severe, and less loaded with incongruous, and often grotesque ornament.

Of late years, travellers have made known the remains of an architecture and sculpture, not very dissimilar to those of the ancient Hindoos, in certain districts of Central America, believed to be the execution of a people anterior to those Mexicans who existed at the period of the invasion of Cortes. Our limited space precludes any detail of those curious structures, which consist of temples, palaces, triumphal and religious monuments—all of which are covered with rude but elaborate sculptures, and mark the existence of a luxurious and wealthy, but semi-barbarous people.*

ASSYRIAN ARCHITECTURE.

One of the most prominent features of Assyrian architecture is the huge artificial mounds upon which the buildings are erected. These mounds, varying in height from thirty to forty feet, rise at once from the surrounding level plain, and seem originally to have been dictated by a desire to render the structures capable of resisting an attack, or probably, as some have conjectured, by religious motives. The buildings which crowned these mounds were approached by inclined planes, and by broad flights of steps cut at intervals in the terraces. The face of the terraces appears to have been at once finished and strengthened by a layer of solid limestone slabs; the material of which the mounds were

* Of these new-world antiquities, the reader will find an ample and most interesting account (accompanied by illustrations) in Stephens's *Yucatan* and *Central America*—published at New York respectively in 1841 and 1843.

constructed—in some cases, rubbish, in others, sun-dried bricks—requiring this protection against the effects of the climate. No margin was left round the building, but the wall was brought up to the extreme edge of the mound or terrace. The buildings themselves were of a very peculiar character; the outline of the structure was nearly square, and contained open courts or large halls, round which were placed chambers of great length in proportion to their breadth, the latter being often twenty-five, while the former was 200 feet. Two façades were usually given to the structure thus arranged, the three entrances with which each façade was furnished being guarded by those colossal figures the forms of which are now comparatively well known, and of one of which we here give an illustration. 'The two side gateways,' says Mr

Fig. 1.

Layard, in describing the Assyrian Court in the Crystal Palace, 'in the more splendid edifices, were flanked by similar figures; and between them and the centre entrance were pairs of the same winged monsters, of somewhat smaller size, placed back to back, and separated by a colossal human figure, usually represented as strangling a lion. These intervening bulls had the human heads turned sideways, so as to look outwards from the front of the building. Each bull was, moreover, flanked by a colossal figure of a deity or priest presenting a pine cone. Thus the south-eastern part of Sennacherib's palace at Kouyunjik consisted of two human-headed bulls—the largest being about nineteen feet high—and of six gigantic human figures, occupying altogether a space of no less than 180 feet. It was continued on either side by sculptured walls, which completed the whole façade.' The sculptured walls here alluded to were of great thickness, constructed of dried bricks, and faced with large slabs of alabaster, sculptured with various subjects. The floors of the edifices were also covered with similarly sculptured slabs, or else with square bricks, containing on their under side the name of the king who constructed the edifice; hence the value of a brick excavated from one of the mounds of the plains of Mesopotamia, as a historical record of rare value. Scroll-work was, however, often substituted for figures on the floor-slabs.

It is these sculptured slabs, forming the panelling of the walls and the pavement of the floors, that possess such an interest, in an archæological point of view, as from them we can learn the daily life of the Assyrians, how they fought their battles, and how cities were besieged and won. The result of the discoveries at Nineveh and elsewhere, has as yet made clear only the method of construction up to the level of the sculptured slabs which lined the walls. How the upper part was constructed—if upper part there were—is matter of pure conjecture. Should the reader wish to ascertain on what these conjectures have been founded, and how ingeniously they are applied to the restoration of Assyrian buildings in the Crystal Palace at Sydenham, we refer him to the interesting little volume forming part of the Crystal Palace Library, entitled the *Assyrian Court*, by H. Austen Layard—or to the more elaborate dissertations in the first volume of Mr Fergusson's valuable *Illustrated Hand-book of Architecture.*

On the relation of Assyrian architecture to Grecian, Mr Fergusson remarks: 'Until the discoveries in Assyria were made, half the history of the architecture of Greece was a riddle and inexplicable mystery. Now all is clear; and with Egypt on the one hand, and Assyria on the other, we are enabled to trace every feature to its source. These two stand, and probably will ever stand, as the primitive styles of the human race, essentially distinct in all their more important features, borrowing very little from each other, but each working out its own objects independently of the other. It seems absolutely hopeless to look for anything anterior to the style of Egypt, which can have had any influence upon it; and so far as we can see, nearly as idle to attempt to find in Asia anything that can have influenced the architectural style of the great Assyrian empire.' On some slabs, which are in a particularly excellent state of preservation, there are sculptures in high relief, in which the horses—apparently of the Arabian breed—are equal to examples of Greek art; and the decorations on the dresses of the kings and other personages, are so fine and well executed, as to resemble Chinese cutting in ivory. There is one very remarkable object on one of the slabs; namely, a perfect centaur, as that conception was represented by the Greeks, with the body of a man united to the body and four feet of the beast, and not merely a human head united to the body of the beast by a short neck, as is the case in most Assyrian figures of that kind.

EGYPTIAN ARCHITECTURE.

The elementary features of Egyptian architecture were chiefly as follows:—1. Their walls were of great thickness, and sloping on the outside. This feature is supposed to have been derived from the mud-walls, mounds, and caverns of their ancestors. 2. The roofs and covered-ways were flat, or without pediments, and composed of blocks of stone, reaching from one wall or corner to another. 3. Their columns were numerous, close, short, and very large, being sometimes ten or twelve feet in diameter. They were generally without bases, and had a great variety of capitals, from a simple square block, ornamented with hieroglyphics or faces, to an elaborate composition of palm-leaves, not unlike the Corinthian capital. 4. They used a sort of concave entablature or cornice, composed of vertical flutings or leaves, and a winged globe in the centre. 5. Pyramids, well known for their prodigious size, and obelisks, composed of a single stone often exceeding seventy feet in height, are structures peculiarly Egyptian. 6. Statues of enormous size, sphinxes carved in stone, and sculptures in outline of fabulous deities and animals, with innumerable hieroglyphics, are the decorative objects which belong to this style of architecture.

The main character of Egyptian architecture is that of great strength with irregularity of taste. This is observable in the pillars of the temples, the parts on which the greatest share of skill has been lavished. In the examples that follow, it may be noticed that sturdiness is the prevailing characteristic. The design has been the support of a great weight, and that without any particular regard to proportion or elegance either as a whole or in parts. When assembled in rows or groups, the columns had an imposing effect, because, from their height and thickness, they filled the eye, and induced the idea of placid and easy endurance. 'Compared with Greek architecture, the Egyptian,' says a recent writer, 'is deficient in beauty, grace, variety, and unity. Powerful and imposing as must have been its effect, combined with its sculptural and pictorial decorations,

its avenues of sphinxes, obelisks, and gigantic statues, yet is there something so fixed, monotonous, and conventional, as to impress the mind with a conviction

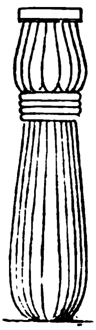


Fig. 2.

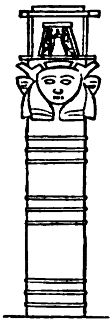


Fig. 3.

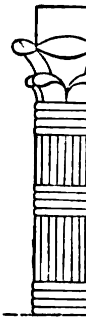


Fig. 4.

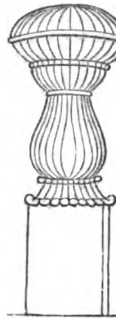


Fig. 5.

that it was unchangeable and incapable of improvement.' In fig. 6, which represents the exterior of a temple, this simple and imposing character is conspicuous. But while the Egyptians thus raised temples and monuments which in strength, solidity, and vastness of dimensions far outstrip those of all other nations,

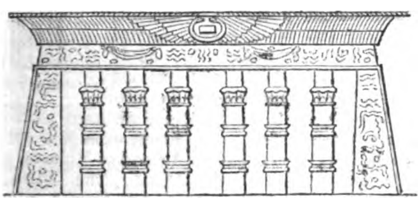


Fig. 6.

yet in street and domestic architecture they were all but utterly deficient. Their streets, if worthy of the name, were narrow and irregular; the generality of their dwellings were mere huts, built of sun-dried bricks, formed of mud and chopped straw; and only among the higher classes was there anything like the enjoyment of a house possessing the elements of elegance or comfort. According to the delineations of Mr Wilkinson, their ordinary houses occupied three sides of a court-yard, which was separated from the street by a wall; while large mansions were detached, having entrances in their several sides, with doors very similar to those of their temples.

GRECIAN STYLE.

From Egypt the architectural art spread to Greece, where it passed from the gigantic to the chaste and elegant. There is no doubt the earliest Greek temples were constructed of wood, the upright supports being united at the top by horizontal lengths, corresponding with the epistylium or architrave. The period during which Greek architecture flourished in the greatest perfection was that of Pericles, about 440 years before Christ, when some of the finest temples at Athens were erected. After this, it declined with other arts, and was carried to Rome, where, however, it never attained the same high character. The Grecian temples were built chiefly of marble, and surrounded or decorated with columns, and had a pleasing effect when situated amidst groves of trees or other kinds of natural scenery; and as the roofs were open to the sky, the beauty of the structures was not deformed by formal rows of windows, such as are now common in modern edifices. Before describing the various orders of Grecian and Roman architecture, it will be advantageous to explain the terms ordinarily employed in reference to the component parts of buildings.

Explanation of Terms.

The *front* or façade of a Greek temple made after the ancient models, or any portion of it, presents four parts occupying different heights (see fig. 8)—namely, the stylobate, or pedestal; the column; the entablature; and the pediment: an order is complete without the pediment. The *pedestal* is the lower part, usually supporting a column; the single pedestal is wanting in most antique structures, and its place supplied by a *stylobate;* the stylobate is either a platform with steps, or a continuous pedestal supporting a row of columns. The lower part of a finished pedestal is called the *plinth*, the middle part is the *dado* or *die*, and the upper part, the *cornice* of the pedestal or *surbase*. The *column* is the middle part, situated upon the pedestal or stylobate. It is commonly detached from the wall, but is sometimes buried in for a portion of its diameter, often as much as half, and is then said to be 'engaged.' *Pilasters.*—The Greeks employed *antæ*, which are flat projecting surfaces attached to the walls of the cells of the temple to receive the ends of the architrave. They were even on the surface, not being fluted: the capital was different from that of the column. The Romans employed pilasters in the place of the Greek antæ, and proportioned them the same as the columns with capitals, bases, and fluted shafts. The lower part of a column, when distinct, is called the *base;* the middle or longest part is the *shaft;* and the upper or ornamented part is the *capital.* The swell of the column is called the *entasis;* the height of columns is measured in diameters of the column itself, taken always at the base of the shaft; the *entablature* is the horizontal continuous portion which rests upon the top of a row of columns; the lower part of the entablature is called the *architrave* or *epistylium;* the middle part is the *frieze*, which, from its usually containing sculpture, was called *zophorus* by the ancients; the upper or projecting part is the *cornice;* the *pediment* is the triangular face produced by the extremity of a roof; the middle or flat portion enclosed by the cornice of the pediment is called the *tympanum*. Pedestals for statues, erected on the summit and extremities of a pediment, are called *acroteria.* An *attic* is an upper part of a building, terminated at top by a horizontal line instead of a pediment, and may be plain or divided by pilasters the height of the attic.

The different *mouldings* in architecture are described from their sections, or from the profile which they present when cut across. Of these, the *torus* is a convex moulding, the section of which is a semicircle, or nearly so; the *astragal* is like the torus, but smaller; the *ovolo* or *echinus* is convex, but its outline is only the quarter of a circle; the *scotia* is a deep concave moulding; the *cavetto* is also a concave, and occupying but a quarter of a circle; the *cymatium* is an undulated moulding, of which the upper part is concave, and the lower convex; the *ogee* or *talon* is an inverted cymatium; the *fillet* is a small square or flat moulding.

A distinguishing characteristic of Roman mouldings is that they are accurately circular, so that they can be struck from a centre; while Greek mouldings form less simple curves, and for the most part must be drawn with a steady hand.

In architectural measurement, a diameter means the width of a column taken at the base; a module is half a diameter; and a minute, the sixtieth part of a diameter.

In representing edifices by drawings, architects make use of the plan, elevation, section, and perspective. The plan is a map or design of a horizontal surface, shewing the ichnographic projection or groundwork, with the relative position of walls, columns, doors, &c. The elevation is the orthographic projection of a front, or

vertical surface; this being represented, not as it is actually seen in perspective, but as it would appear if seen from an infinite distance (fig. 8). The section shews the interior of a building, supposing the part in front of an intersecting plane to be removed (fig. 21). The perspective shews the building as it actually appears to the eye, subject to the laws of scenographic perspective (fig. 28). The three former are used by architects for purposes of admeasurement; the latter is used also by painters, and is capable of bringing more than one side into the same view, as the eye actually perceives them. As the most approved features in modern architecture are derived from buildings which are more or less ancient, and as many of these buildings are now in too dilapidated a state to be easily copied, recourse is had to such imitative restorations, in drawings and models, as can be made out from the fragments and ruins which remain. In consequence of the known simplicity and regularity of most antique edifices, the task of restoration is less difficult than might be supposed. The groundwork, which is commonly extant, shews the length and breadth of the building, with the position of its walls, doors, and columns. A single column, whether standing or fallen, and a fragment of the entablature, furnish data from which the remainder of the colonnade and the height of the main body can be made out and restored.

Grecian temples are well known to have been constructed in the form of an oblong square, or parallelogram, having a *colonnade* or row of columns without, and a walled *cell* within. The part of the colonnade which formed the front portico was called the *pronaos*, and that which formed the back part the *posticus*. There were, however, various kinds of temples, the styles of which differed: thus, the *prostyle* had a row of columns at one end only; the *amphiprostyle* had a row at each end; the *peripteral* had a row all round; the *dipteral* had a double row all round; and the *psuedo-dipteral* had the inner range of columns of the flanks attached to the walls.

The theatre of the Greeks, which was afterwards copied by the Romans, was built in the form of a horseshoe, being semicircular on one side and square on the other. The semicircular part, which contained the audience, was filled with concentric seats, ascending from the centre to the outside. In the middle or bottom was a semicircular floor, called the *orchestra*. The opposite or square part contained the actors. Within this was erected, in front of the audience, a wall, ornamented with columns and sculpture, called the *scena*. The stage or floor between this part and the orchestra was called the *proscenium*. Upon this floor was often erected a movable wooden stage, called by the Romans *pulpitum*. The ancient theatre was open to the sky, but a temporary awning was erected to shelter the audience from the sun and rain.

Orders.

Aided, doubtless, by the examples of Egyptian art, the Greeks gradually improved the style of architecture, and originated those distinctions which are now called the 'Orders of Architecture.' By this phrase is understood certain modes of proportioning and decorating the column and its entablature. They were in use during the best days of Greece and Rome for a period of six or seven centuries. They were lost sight of in the dark ages, and again revived by the Italians at the time of the restoration of letters. The Greeks had three orders—called the Doric, Ionic, and Corinthian. These were adopted and modified by the Romans, who added two others—the Tuscan and Composite.

Doric.—This is the earliest of the Greek orders, and we see in it a noble simplicity on which subsequent orders were founded. Compared with the best of the Egyptian models, it exhibits a great advance in purity of taste. From the remains of ancient art, it is found that the Doric varied in its proportions. The column, in its examples at Athens, is about six diameters in height; but in those of older date, as those at Pæstum, it is only four or five. One of the most correct examples is that given in fig. 7. The shaft of the Doric column had no base, ornamental or otherwise, but rose directly from the smooth pavement or stylobate. It had twenty flutings, which were superficial, and separated by angular edges. The perpendicular had an entasis, or swelling outline. The Doric capital was plain, being formed of a few annulets or rings, a large echinus, and a flat stone at top called the *abacus*. The architrave was plain; the frieze was intersected by oblong projections called triglyphs, divided into three parts by vertical furrows, and ornamented beneath by *guttæ*, or drops. The spaces between the triglyphs were called *metopes*, and commonly contained sculptures. The sculptures, representing Centaurs and Lapithæ, carried by Lord Elgin to London, were metopes of the Parthenon, or temple of Minerva, at Athens. The cornice of the Doric order consisted of a few large mouldings, having on their under side a series of square sloping projections, resembling the ends of rafters, and called *mutules*. These were placed over both triglyphs and metopes, and were ornamented on their under side with circular guttæ. The Romans, in adopting the Doric, greatly spoiled its simplicity and grandeur by unduly lengthening the shaft, and making other tasteless alterations. To have a just idea of the Doric, therefore, we must go back to the pure Grecian era. The finest examples are the temple of Theseus, and that of Athena or Minerva, called the Parthenon (fig. 8) at Athens. The Parthenon, which is now a complete ruin, has formed a model

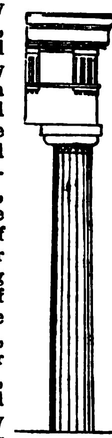


Fig. 7.

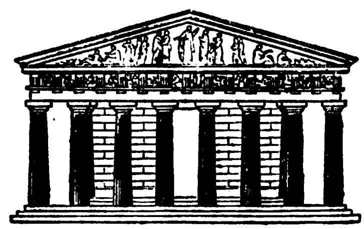


Fig. 8.—Façade of the Parthenon.

in modern architecture. It was built by the architect Ictinus, during the administration of Pericles, and its decorative sculptures are supposed to have been executed under the direction of Phidias. The platform or stylobate consists of three steps, the uppermost of which is 227 feet in length, and 101 in breadth. The number of columns is eight in the portico of each front, and seventeen in each flank, besides which there is an inner row of six columns at each end of the cell. The proportional height of the columns is five diameters and fifty-six minutes, and they diminish thirteen minutes in diameter from bottom to top. The sculpture of the frieze of the peristyle, represented the combats of the Centaurs and Lapithæ; those of the eastern pediment represented the fabulous birth of Minerva; and those on the western, the contests between the goddess and Neptune for the right of presiding over the city. The interior was divided in unequal parts by a cross-wall; the smaller portion was called the *opisthodomus*, where the public treasure was kept; in the larger division stood the famous statue of Minerva, wrought in ivory and gold, by Phidias. The building was destroyed by the explosion of a bomb-shell during the siege by the Venetians in 1687.

Speaking of these splendid objects of art, a modern authority observes: 'Of their effect it is impossible to form a competent idea without seeing one. And whence, it may be asked, does this interest arise? From their simplicity and harmony: simplicity, in the long unbroken lines which bound their forms, and the breadth and boldness of every part; harmony, in the evident fitness of every part to all the rest. The entablature, though massive, is fully upborne by the columns, whose spreading abaci receive it, and transmit the weight downwards by the shafts, which rest on a horizontal and spreading basement; the magnitude of every part being determined by the capacity of the sustaining power. Besides graceful and elegant outline, and simple and harmonious forms, these structures possess a bewitching variety of light and shade, arising from the judicious contour and arrangement of mouldings, every one of which is rendered effective by the fluting of the columns, and the peculiar form of the columnar capital, whose broad square abacus projects a deep shadow on the bold ovolo, which mingles it with reflections, and produces on itself almost every variety. The play of light and shade, again, about the insulated columns, is strongly relieved and corrected by the deep shadows on the walls behind them; and in the fronts, where the inner columns appear, the effect is enchanting. For all the highest effects which architecture is capable of producing, a Greek peripteral temple of the Doric order is perhaps unrivalled.'

Ionic.—In this order, the shaft begins to lengthen, and to possess a degree of ornament, but still preserving great simplicity of outline. In the best examples, as represented in fig. 9, the column was eight or nine diameters in height. It had a base often composed of a torus, a scotia, and a second torus, with intervening fillets. This is called the Attic base. Others were used in different parts of Greece. There is a remarkable distinction in the form of the flutings to the shafts of the Greek Doric and Ionic orders; the divisions of the flutes in the Doric being brought to an arris, or edge, while in the Ionic, the divisions of the flutes are 'fillets.' The capital of this order consisted of two parallel double scrolls, called *volutes*, occupying opposite sides, and supporting an abacus, which was nearly square, but moulded at its edges. These volutes have been considered as copied from ringlets of hair, or perhaps from the horns of Jupiter Ammon. When a column made the angle of an edifice, its volutes were placed, not upon opposite, but on contiguous sides, each fronting outwards. In this case, the volutes interfered with each other at the corner, and were obliged to assume a diagonal direction. The Ionic entablature consisted of an architrave and frieze, which were continuous or unbroken, and a cornice of various successive mouldings, on the lower portion of which was often an angular member, divided by deep cuttings into 'dentels or square teeth: this member is called the dentel band.' The examples at Athens of the Ionic order were the temple of Erectheus and the temple on the Ilissus, both now destroyed. Modern imitations are common in public edifices.

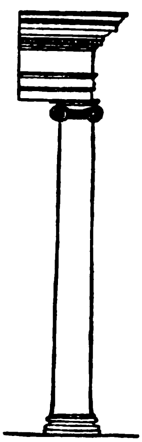


Fig. 9.

Corinthian.—This was the lightest and most highly decorated of the Grecian orders (fig. 10). The base of the column resembled that of the Ionic, but was more complicated. The shaft was often ten diameters in height, and was fluted like the Ionic. The capital was shaped like an inverted bell, and covered on the outside with two rows of leaves of the plant acanthus, above which were eight pair of small volutes. Its abacus was moulded and concave on its sides, and truncated at the corners, with a flower on the centre of each side. The entablature of the Corinthian order resembled that of the Ionic, but was more complicated and ornamented, and had, under the cornice, a row of large oblong projections, bearing a leaf or scroll on their under side, and called *modillions.* No vestiges of this order are now found in the remains of Corinth, and the most prominent example at Athens is in the choragic monument of Lysicrates. The Corinthian order was much employed in the subsequent structures of Rome and its colonies. The finest Roman example of this order is that of three columns in the Campo Vaccino at Rome, which are commonly considered as the remains of the temple of Jupiter Stator. This example has received the commendation of all modern artists, yet has seldom been executed in its original form. This is probably owing to its excessive richness and delicacy, which render its adoption very expensive; and perhaps the modification of it by Vignola is preferable to the original, possessing a sufficient enrichment without the excessive refinement of the other. In this order, the base is one module in height; the shaft, sixteen modules twenty minutes; and the capital, two modules ten minutes—thus giving ten diameters to the whole column. The architrave and frieze are each one module twelve minutes in height, and the cornice two modules and nine minutes. The cornice is distinguished by modillions interposing between the bed-mouldings and corona; the latter is formed by a square member surmounted by a cymatium, supported by a small ogee: the former is composed of dentels, supported by the ovolo, and covered by the cyma reversa. When the order is enriched, which is usually the case, these mouldings, excepting the cymatium, are all sculptured: the column is also fluted, and the channels are sometimes filled to about a third of their height with cablings, which are cylindrical pieces let into the channels. When the column is large, and near the eye, these are recommended as strengthening them, and rendering the fillets less liable to fracture; but when they are not approached, it is better to leave the flutes plain. They are sometimes sculptured, but this should only be in highly enriched orders.

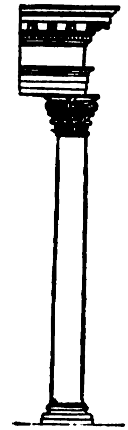


Fig. 10.

The flutes are twenty-four in number, and commonly semicircular in their plan in the Roman examples. The Corinthian base is similar to that of the Composite order, excepting that two astragals are employed between the scotiæ instead of one; but the Attic is usually employed for the reasons before assigned.

'The Corinthian order,' says Sir William Chambers, 'is proper for all buildings where elegance, gaiety, and magnificence are required. The ancients employed it in temples dedicated to Venus, to Flora, Proserpine, and the nymphs of fountains, because the flowers, foliage, and volutes with which it is adorned, seemed well adapted to the delicacy and elegance of such deities. Being the most splendid of all the orders, it is extremely proper for the decoration of palaces, public squares, or galleries and arcades surrounding them; and on account of its rich, gay, and graceful appearance, it may with propriety be used in theatres, in ball or banqueting rooms, and in all places consecrated to festive mirth or convivial recreation.'

Caryatides.—The Greeks sometimes departed so far from the strict use of the orders, as to introduce statues in the place of columns, to support the entablature. Statues of slaves, heroes, and gods appear to have been employed occasionally for this purpose. The principal specimen of this kind of architecture which remains is in a portico called Pandroseum, attached to the temple

of Erectheus at Athens, in which statues of Carian females, called Caryatides, are substituted for columns. One of these statues has been carried to London.

ROMAN STYLE.

Strictly speaking, Roman architecture possessed little originality; it was founded on copies of the Greek models, and these were modified to suit circumstances and tastes. The Roman examples of Doric and Ionic had very different proportions from the Greek. The number of orders was augmented by the addition of the Tuscan and Composite; the former being the Doric stripped of its distinctive ornaments; the latter, a combination of the Ionic and Corinthian. The distinguishing feature of the Roman style is boldness of execution and elaborate profusion of ornament—as by their adaptation of the principles of the arch, they were enabled to rear structures of greater extent and complexity of design. In the Coliseum, for example, columns and arches are piled upon columns and arches in the interior, and must have struck the beholder with wonder and astonishment; yet in the external plan, the building has been pronounced 'a gigantic illustration of architectural blunders.'

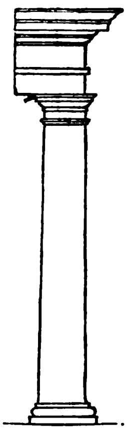


Fig. 11.

Tuscan.—This order is not unlike the Doric, and is chaste and elegant. As represented in fig. 11, the shaft had a simple base, ornamented with one torus, and an astragal below the capital. The proportions were seven diameters in height. Its entablature, somewhat like the Ionic, consisted of plain running surfaces. There is no vestige of this order among ancient ruins, and the modern examples of it are taken from the descriptions of Vitruvius.* The general effect is strength with simplicity, and the order is considered to be well adapted for such buildings as prisons, public halls, and inferior parts of edifices.

Composite.—This order, as the name imports, is a compound of other orders—namely, the Corinthian and Ionic (fig. 12). The proportion and distribution of its parts do not differ much from those of the Roman Corinthian. It would appear from these efforts, as well as from all subsequent attempts, that the Greeks attained the highest state of improvement of which their style was susceptible, and that, consequently, all schemes to execute something better must prove abortive. The higher class of Roman architects were convinced of this fact, and very judiciously held to the Corinthian order in all their finest buildings, both in Rome and in the provinces. Thus the Corinthian prevails among the celebrated ruins of Palmyra and Balbec, and other great cities founded by Roman provincials.

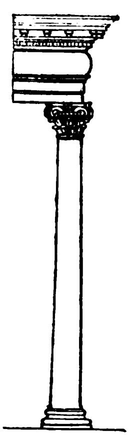


Fig. 12.

The temples of the Romans sometimes resembled those of the Greeks, but often differed from them. The Pantheon, which is the most perfectly preserved temple of the Augustan age, is a circular building, lighted only from an aperture in the dome, and having a Corinthian portico in front. Though stripped of its external ornaments, to furnish materials to decorate the modern cathedral of St Peter's, it is still incomparably the finest. It is a perfect circle, of 180 feet in diameter. 'Its beauty,' says Forsyth, 'consists in its admirable proportions; and its portico, 110 feet in length by 44 in depth, supported by sixteen Corinthian columns of Oriental granite, has a most majestic appearance. Its portal is more than faultless: it is positively the most sublime result that was ever produced by so little architecture.'

The amphitheatre differed from the theatre in being a completely circular, or rather elliptical building, filled on all sides with ascending seats for spectators, and leaving only the central space, called the *arena*, for the combatants and public shows. The Coliseum is a stupendous structure of this kind. It consists of a vast ellipse, the length of the longest diameter being 620, and that of the shortest 513 feet, so that it covers about five and a quarter acres of ground! The longest diameter of the arena has been variously given at from 287 to 300, and the shortest at from 180 to 190 feet; the space between the arena and the outer wall (from 160 to 167 feet) being occupied by the walls, corridors, and seats, that rose, tier above tier, from the wall round the arena nearly to the top of the outer wall. The latter, which is about 179 feet in height, consists of three rows of vaulted arches, rising one above another, exclusive of which it had, when perfect, upper works of wood. This colossal amphitheatre is said to have had seats for 87,000 spectators, and standing-room for 20,000 more! Belonging to the same class of buildings were the circuses, of which Rome had at one time no fewer than fifteen. Of these, the chief was the Circus Maximus, of which there are now no remains, but of whose dimensions we may judge from the statement of Pliny, that it was capable of accommodating 200,000 spectators.

The triumphal arches were commonly solid oblong structures, ornamented with sculptures, and open with lofty arches for passengers below. The edifice of this kind most entire in the present day is the triumphal arch of Constantine at Rome, represented in fig. 13. This structure is ornamental, and far from inelegant, but it contains much that is tasteless, inasmuch as being

Fig. 13.

without meaning; and there is also an undue overloading of embellishment, or at least frittering away in details. Carrying the eye up the columns, and dissecting their individual bearings, we perceive that each may be resolved into the shafting represented on a larger scale in fig. 14, which is evidently anomalous in design, and inconsistent with the dignified simplicity of the pure Grecian models. The arch of Constantine has been copied at Paris, in the structure erected by Napoleon in front of the Tuileries.

The *basilica* of the Romans was a hall of justice, used also as an Exchange or place of meeting for merchants. It was lined on the inside with colonnades of two stories, or with two tiers of columns, one over the other. The earliest Christian churches at Rome were sometimes called *basilicæ*, from their possessing an internal colonnade. The *thermæ*, or baths, were vast structures,

* Vitruvius was a celebrated writer on architecture, who is supposed to have flourished in the time of Julius Cæsar and Augustus. His treatise on architecture was first printed at Venice in 1497. An English translation appeared in 1771. A new translation by Wilkins was published in 1812.

in which multitudes of people could bathe at once. As they now exist, they are an assemblage of naked, half-dilapidated brick-walls, which surprise by their huge size and the extent of ground they cover—those of Caracalla, for example, occupying not less than twenty-eight acres! In the palmy days of Rome, these were fitted not only as hot and cold water baths, but as gymnasia, reading and lecture rooms, gardens, theatres, and the like—being, as a whole, the most gigantic places of recreation ever built in any age or in any country.

ANGLO-NORMAN STYLE.

By Anglo-Norman architecture is understood that style which prevailed in England immediately after the Conquest, and which received the epithet Norman, as coming directly from Normandy. It is considered extremely doubtful if any specimens of the architecture of the Anglo-Saxons before the Conquest are now extant. At all events, the Anglo-Saxon and the Norman were in their essential elements the same, being both only local modifications of the style called Romanesque, which then prevailed in the west of Christendom generally, being derived, along with Christianity, from the later Roman. The principal characteristic of the Norman architecture is the circular arch, springing either from a single column, or from a pier decorated with half columns or light shafts, the evident origin of the clustered pillar of a later date. The walls are so massive as to render buttresses unnecessary. The windows are small in proportion, and generally simple in form, though sometimes

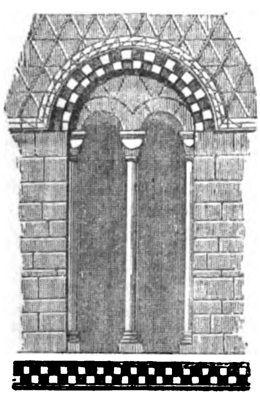


Fig. 14.—Window from Caxton Church.

divided by a column into two lights, within the external arch. In Anglo-Norman works, the greatest display of ornament was lavished on the doorways, which are often deeply recessed, the arch consisting of a succession of enriched bands, one within another.

The peculiarities of the style may be met with in many of the English cathedrals—as, for instance, in those of Norwich, Canterbury, Gloucester, Worcester, &c.; and exemplifications of its external characteristics may also be seen in some of these edifices, and in the White Tower, Tower of London.

GOTHIC OR POINTED STYLE.

The term Gothic is a modern error, which, being now beyond correction, is suffered to remain as the generally distinguishing appellation of the kind of architecture possessing pointed arches. This style, according to some, originated in Germany about the middle of the thirteenth century; according to others, it was introduced by the Crusaders from the East, where it is said to have been known long before that period. Be this as it may, for three centuries after its introduction, it was zealously pursued as the leading fashion for ecclesiastical structures all over Europe. Executed by a class of skilled artisans, who wandered from country to country,* the finest specimens of the pointed style are the cathedrals of Strasburg, Cologne, and Antwerp, and the splendid abbeys of Melrose and Westminster (fig. 15).

Fig. 15.

The origin of the Gothic or pointed arch is one of the disputed points of architecture. Some, as Bishop Warburton, refer it to the accidental interlacings and crossings of the boughs of trees. Other theories, equally fanciful, have been promulgated; but now the opinion seems to be generally held, that the pointed arch had its origin in the intersections of the rounded or circular arches of the Norman architecture—a very common arrangement in this style being a series of arches struck from centres distant from each other by spaces equal to the semi-diameter of the arch. It is, however, worthy of notice, that the recent discoveries amidst the ruins of Nineveh shew that the pointed arch was familiar to the Assyrians—a large sewer with a pointed arch having been met with there. Specimens of the intersecting arches may be met with in some of our old abbeys, as Fountain's Abbey, Kirkstall Abbey, in Yorkshire; the Temple Church, London; St Cross, Winchester, &c.

In England, the transition from the Norman to the pointed style of arch is observed in various old buildings. In the Temple Church, the two arches may be found united, and other specimens may be seen in the church of St Cross, near Winchester; and Fountain's Abbey, Rivaulx Abbey, and Roche Abbey, in Yorkshire.

When the circular arch disappeared, the Early English

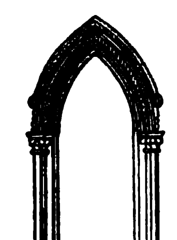


Fig. 16.—York.

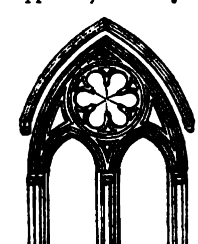


Fig. 17.—Westminster.

Gothic commenced (1189). The windows of this style were at first very narrow in comparison with their

* We here allude to the order or craft of Freemasons, the origin of whose associations may be dated from the ninth or tenth century, and who attained their greatest numerical strength and importance at the introduction of the Gothic or pointed style of architecture. Afterwards the order became a speculative society, unconnected with the practice of architecture, and finally has sunk before the spread of universal intelligence, and a common philanthropy which recognises all men as brothers.

height; they were called lancet-shaped, and were considered very elegant. Two or three were frequently seen together, connected by dripstones, and divided by narrow widths of walling in courses: by degrees the divisions between the window-lights were reduced, and assumed the form of shafts and mouldings. As the style advanced, the same window was divided into several lights, and frequently finished at the top by a light in the form of a lozenge, circle, trefoil, or other ornament. Figs. 16, 17 are two specimens of the windows of this period.

About the year 1300, the architecture became more ornamental, and from this circumstance received the name of the Decorated English Style, which is considered the most beautiful for ecclesiastical buildings. The windows of this style are very easily distinguished: they are divided into several lights by mullions, which are upright or perpendicular narrow shafts, branching out at the top into tracery of various forms, such as trefoils, circles, and other figures. In the accompanying illustration, fig. 18 represents a window of this kind;

Fig. 18.

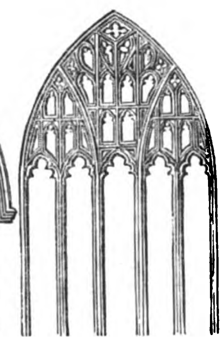


Fig. 19.

fig. 19, from the choir, York, exhibits the transition to what has been called the Perpendicular Style, from the lines of division being upright.

In this third modification of the English Gothic, which is claimed as peculiarly national, ornament after ornament was added, till simplicity disappeared beneath the extravagant additions; and about the year 1380, the architecture became so overloaded and profuse, that it obtained the title of Florid. King's College Chapel, Cambridge, and Henry VII.'s Chapel at Westminster, are considered perfect examples of this style. Many small country churches are built in it; and their size not admitting of much ornament, they are distinguished from structures of a later date by mouldings running round their arches, and generally by a square head over the obtuse-pointed arch of the door. A peculiar ornament of this style is a flower of four leaves, called, from the family reigning at that period, the Tudor Flower.

Definitions of Parts.

Gothic architecture being for the most part displayed in ecclesiastical edifices, it may be of service to explain the usual plan and construction of these buildings. A church or cathedral is commonly built in the form of a cross, having a tower, lantern, or spire erected over the place of intersection. The part of the cross situated towards the west is called the *nave;* the opposite or eastern part is called the *choir*, and within this is the *chancel.* The transverse portion, forming the arms of the cross, is called the *transept*, one limb being called the northern, and the other the southern transept. To the principal figure of a cathedral church are appended subsidiary buildings, as (1) *Lady-chapel;* (2) *Chapter-house;* (3) *Cloisters*, &c.

Generally the nave is larger than the choir. If the nave, choir, and transepts be all of the same dimensions, the form is that of a Greek cross. When the nave is

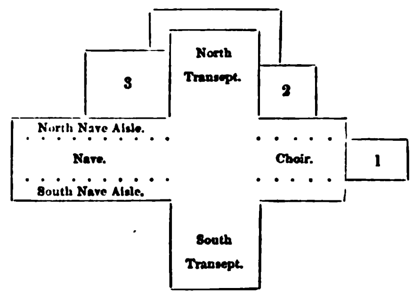


Fig. 20.

longer than the other parts, forming a cross of an ordinary shape, the edifice is said to be in the form of a Latin cross. The spaces or passages between the side-walls and the rows of columns or piers that support the roof, are called *ailes* or *aisles* (wings); a term sometimes extended, improperly, to the middle division of the nave. Originally, the floors of all such edifices were unencumbered with fixed pews or seats, and as the floors were usually of mosaic or tesselated pavement, the effect was exceedingly imposing.

The ceilings of the most important ecclesiastical buildings of this period were executed in stone, formed into all varieties of curves by the intersections of arches

Fig. 21.

from different directions. The intersections are called *groins*, which were in the later examples ornamented with mouldings called *ribs.* The vaulted ceilings are protected on the outside by a timber roof covered with lead. Many churches, however, have the roof-timbers exposed, without any stone or other ceiling beneath. The roof of the central part of the nave and choir is higher than that of the aisles, and the wall of this elevated central part above the aisle-roof is called the *clerestory.* The vaults are most skilfully poised, and their outward thrust is counteracted by a system of *buttresses* outside (fig. 22), which rise by gradations from a broad basis to narrow-pointed *pinnacles.* Slanting braces, called *flying* buttresses, springing from the main buttresses, and spanning the aisle-roof to the clerestory wall, sustain the lateral pressure of the central roof. Any high building erected above the roof is called a *steeple;* if square topped, it is a *tower;* if long and acute, a *spire;* and if short and light, a

lantern. Towers of great height, in proportion to their diameter, are called *turrets.*

The upper edge of a wall, if straight, is called a *parapet;* if indented, a *battlement.* Gothic windows were commonly crowned with an acute arch; they were long and narrow, or if wide, were divided into perpendicular lights by *mullions.* The lateral spaces on the upper and outer side of the arch are called *spandrels;* and the ornaments in the top, collectively taken, are the *tracery.* An *oriel window* projects from the wall, and is supported on a *corbel,* or bracket; a *bay-window* rises from the ground, and is semi-octagonal, or semi-hexagonal, or polygonal in plan; a *wheel* or *rose window* is large and circular; a *corbel* is a bracket or short projection from a wall, serving to sustain a statue, the springing of an arch, &c.; the Gothic term *gable,* indicates the erect end of a roof, and answers to the Grecian pediment, but is generally more acute.

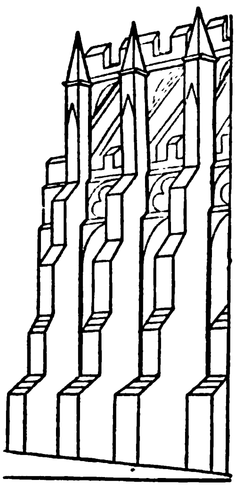


Fig. 22.

The polished tastes of the architects employed in constructing Gothic edifices, led to numerous devices in the form of the pillars. In early examples, the column was single and round, or polygonal in form; which, as the style advanced, was composed of seemingly a cluster of smaller pillars, and this had always the lightest effect; but occasionally the column was given the appearance of several shafts twisted, or of a single shaft with a festoon of flowers twined spirally around it. In the chapel at Roslin there are some highly ornamented pillars of this kind.

The Gothic style of building is more imposing, and more difficult to execute than the Grecian. This is because the weight of its vaults and roofs is upheld at a great height by supporters acting at single points, and apparently but barely sufficient to effect their object. Great mechanical skill is necessary in balancing and sustaining the pressures; and architects at the present day, hampered by principles of economy, find it difficult to accomplish what was achieved by the builders of the middle ages.

ITALIAN STYLE.

After the dismemberment of the Roman Empire, the arts degenerated so far that a custom became prevalent of erecting new buildings with the fragments of old ones, which were torn down for the purpose. This gave rise to an irregular style of building, which continued to be imitated, especially in Italy, during the dark ages. It consisted of Grecian and Roman details, combined under new forms, and piled up into structures wholly unlike the antique originals. Hence the names Græco-Gothic and Romanesque architecture have been given to it.

After this came the *Italian style,* which was professedly a revival of the classic styles of Greece and Rome, but adapted to new manners and wants—a kind of transition from ancient to modern times. Its great master was Andrea Palladio, a Venetian (born 1518—died 1580). This highly accomplished man expelled much of the Græco-Gothic taste, and established in the sixteenth century what may be called a new era in architecture—sometimes styled the Renaissance. The majestic simplicity of the ancient orders was always present to the mind of Palladio, and he has left behind him many beautiful buildings which attest the purity of his taste. The writer in the *Encyclopædia Britannica* thus describes some peculiarities of the Italian style: 'Prostyles being almost unknown in Italian architecture, antæ are not often required. Pilasters, however, are very common—so common, indeed, that they may be called pro-columns, as they are often used as an apology for applying an entablature. They are described as differing from columns in their plan only, the latter being round, and the former square, for they are composed with bases and capitals; they are made to support entablatures according to the order to which they belong, and are fluted and diminished with or without entasis, just as columns of the same style would be. When they are fluted, the flutes are limited to seven in number on the face, which, it is said, makes them nearly correspond with the flutes of columns; and their projection must be one-eighth of their diameter or width when the returns are not fluted; but if they are, a fillet must come against the wall. Pedestals are not considered by the Italo-Vitruvian school as belonging to the orders, but they may be employed with them all, and have bases and surbases or cornices to correspond with the order with which they may be associated. With columnar arrangements, moulded imposts and archivolts are used; the former being made rather more than a semi-diameter of the engaged columns in height, and the latter, exactly that proportion (fig. 23).

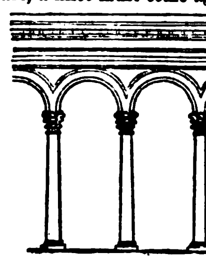


Fig. 23.

'Balustrades are used in various situations, but their most common application is in attics, or as parapets, on the summits of buildings, before windows, in otherwise close-continued stereobates, to flank flights of steps, to front terraces, or flank bridges. Their shapes and proportions are even more diversified than their application; that of most frequent use is shaped like an Italian Doric column, compressed to a dwarfish stature, and consequently swollen in the shaft to an inordinate bulk in the lower part, and having its capital, to the hypotrachelium, reversed to form a base to receive its grotesque form.

'There is considerable variety and beauty in the foliate and other enrichments of an architectural character in many structures in Italy, but very little ornament enters into the columnar composition of Italian architecture. Friezes, instead of being sculptured, are swollen; the shafts of columns are very seldom fluted, and their capitals are generally poor in the extreme; mouldings are indeed sometimes carved, but not often; rustic masonry, ill-formed festoons, and gouty balustrades, for the most part supply the place of chaste and classic ornaments.'

SARACENIC, MOORISH, AND BYZANTINE STYLES.

The Arabs, or Saracens, as they are more usually called, and the Moors, introduced into Spain certain forms of architecture which differed considerably from the Grecian in appearance, though founded on its remains in Asia and Africa. The chief peculiarity of this architecture was the form of the arch: the Saracens are understood to have made it of greater height than width, thus constituting more than half a circle, and being therefore unscientific and comparatively insecure (fig. 24); while the Moorish style was principally distinguished by arches in the form of a horseshoe, or a crescent. The Saracens and Moors, however, were so much one people, that the works of each are not easily pointed out in the present day; both styles were highly ornamented with flowery tracery, called *arabesque,*

the decorations being for the most part sunk below the surfaces of the walls, and highly wrought in various colours of the brightest description and contrast. The pillars supporting the arches were generally slender and elegant. The crescent-like or bulging dome of the Oriental mosque was likewise introduced by the Moorish architects into Europe. It is common, for example, in the church-spires of the Netherlands, having been brought thither by the Spaniards when in possession of the country.

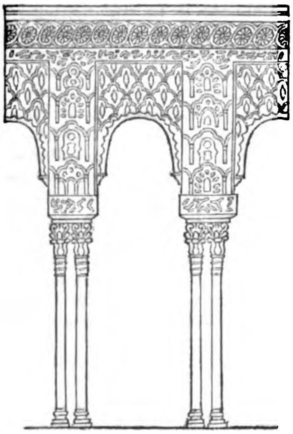


Fig. 24.

We associate with these styles another, which arose at Constantinople, called the Byzantine, likewise formed on the remains of Grecian art, and partaking of a slightly Eastern character. It became known in Western Europe along with the Lombard, another degenerate Grecian style, about the ninth and tenth centuries. The two united received the name of the Lombard-Byzantine, and were employed upon the cathedrals of Worms and Mayence, and several other ecclesiastical structures in Germany. This style is distinguished by small arches resting on connecting central pillars, like the Saracenic, and sometimes there are rows of such arches one above another. Either pure or mixed, the Byzantine style remained in vogue till it was superseded by the Gothic, about the middle of the thirteenth century.

CHINESE STYLE.

Of the date and origin of Chinese architecture, we know nothing, except that it is evidently founded on the type of the Oriental tent—the primitive habitation of the nomadic Tatars, the ancestors of the Chinese. So close, indeed, is the resemblance to the tent, that, from the accounts of travellers, a Chinese city looks like a large permanent encampment. Chinese roofs are concave on the upper side, as if made of canvas instead of wood. A Chinese portico is not unlike the awnings spread over shop-windows in summer-time. The veranda, sometimes copied in dwelling-houses, is a structure of this sort. The Chinese towers and pagodas have concave roofs, like awnings, projecting over their several stories. A representation of this barbaric style of erection is given in fig. 25.

Fig. 25.

Such structures are built with wood or brick; stone is seldom employed. Composed chiefly of timber, the houses of the Chinese are light and gay in appearance—the roofs, porticos, and verandas being generally variegated with different colours and varnishes. 'The law,' says Mr Cleghorn, 'has from time immemorial laid down strict regulations, rigidly enforced, for the plans, dimensions, and materials of the houses of all ranks and castes—from the palaces of the emperor and the princes of the first, second, and third degree, to the habitations of the nobles of the imperial family, the grandees of the empire, the citizens, and all classes.' Hence the extraordinary uniformity remarked by all travellers.

Without the gates of several cities in China, lofty towers or pagodas are erected, which, according to Davis, are of a religious nature, and, like the steeples of churches, were at first attached to temples. The most remarkable of these—and which may be taken as an illustration of the whole—is that of Nankin, called the Porcelain Tower (fig. 26), from the roofs of its different stories or stages being covered with porcelain tiles beautifully painted. It is of an octangular figure, contains nine stories, and is about 200 feet high, raised on a very solid basis of brickwork. The wall at the bottom is at least twelve feet thick; and the building gradually tapers to the top, which forms a sort of spire. It is surrounded by a balustrade of rough marble, and has an ascent of twelve steps to the first floor, from whence one may ascend to the ninth story by very narrow and incommodious stairs. Between every story there is a kind of penthouse on the outside of the tower, from the eaves of which are suspended little brass bells, diminishing in size as they approach the top, and set in motion by the wind. Each story is formed of strong beams of timber, well boarded; the ceilings of the rooms are adorned with paintings; and the light is admitted through lattices of wire. There are likewise niches in the walls filled with idols; and the variety of ornaments that embellish the whole, render it one of the most unique, as it is undoubtedly one of the most beautiful structures in China.

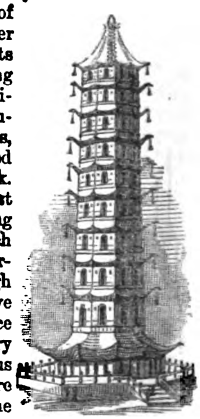


Fig. 26.

TUDOR—ELIZABETHAN—MODERN GOTHIC.

Throughout England may be seen many aged castles, some still in a state of good preservation, but the greater number in ruins, and occupying, with their picturesque remains, the summit of a rising-ground or rocky precipice. These castles are of a style which prevailed during the feudal ages in Europe, and was brought to this country by the Normans, who erected them as fastnesses into which they might retire, and oppress the country at pleasure. The same kind of buildings are also frequent in Scotland, where the barons ruled with the same feudal power as in the southern parts of the island.

The feudal castles in England, like those on the Rhine, consisted for the most part of a single strong tower or keep, the walls of which were from six to ten feet thick, and the windows, only holes of one or two feet square, placed at irregular intervals. The several floors were built on arches, and the roof was flat or battlemented, with notches in the parapet, from which the inhabitants or retainers of the chieftain might defend themselves with instruments of war. The accommodations for living were generally mean, and what would now be called uncomfortable. Around, or in front of the main tower, there was usually a courtyard, protected by a high wall, and the arched entrance was carefully secured by a falling gate or portcullis. Outside, there was in many cases a regular wet ditch or fosse. Castles of greater magnitude consisted of two or more towers and inner buildings, including a chapel and offices for domestics, and horses and other animals. Some of them were on a great scale, and possessed considerable grandeur of design.

As society advanced, and civil tranquillity was established, these military strengths gradually assumed a character of greater elegance, and less the appearance of

defence. The wet ditch disappeared, and was superseded by a lawn or shrubbery. Instead of the drawbridge and portcullis, there was a regular approach and gate of ordinary construction. The windows became larger, and were fitted with glass frames; and stone was abandoned for the greater comfort of wooden floors. Instead also of a bare region around, in which no foe might lurk, gardens were established, and a long avenue of trees led to the front of the modernised mansion. In some instances, the pepper-box turrets at the upper corners of the buildings remained. Of the class of structures that sprung up in this period of transition, which we may refer in England to the fifteenth and sixteenth, and in Scotland, to the seventeenth centuries, there are several highly interesting remains. These edifices of the nobility and gentry were no longer called castles: they took the name of *halls;* and such had attained so great a pitch of magnificence in the reigns of Henry VIII. and Elizabeth, as to have subsequently given a name to a new style—namely, the *Elizabethan.*

'The quadrangular embattled mansion of the last Henries,' says a writer in the *Quarterly Review,* 'affords scope for the display of much grandeur and magnificence, and adapts itself more conveniently to the plan of a modern house. The carved oriel, and deep many-lighted bay-window, often projecting in a multitude of capricious angles and curves, besides the regular octagon, the panelled angled turrets, with richly embossed finials, and the wreathed chimney-shafts, are characteristic beauties of this class of building. The gabled manor-house, together with these ornamental features, admits at the same time of a much greater irregularity of form and outline, so as to accommodate itself to every variety of disposition, and to buildings of every size, from the baronial residence to the parsonage and grange. All the forms which particularly mark the Elizabethan style, may be wrought in the cheapest materials with comparatively little labour; and a small portion of ornamental work, tastefully disposed, is capable of producing very considerable effect. Lastly, the Elizabethan house is distinguished by the number and size of its rectangular and many-mullioned windows, which gave a peculiar lightness and elegance to its several parts. The roof-line may be either horizontal or broken with gables, turrets, and cupolas. In either case, it is enriched with perforated parapets, balustrades, or other architectural devices, while similar embellishments ornament the entrance, and the terraces which connect the building with the garden.'

Fortunately, this light and elegant style of domestic architecture is gradually superseding the bald Græco-Italian style of the eighteenth century. A better taste

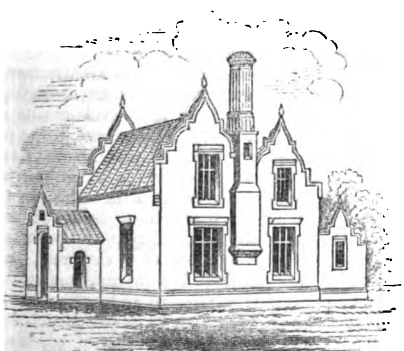


Fig. 27.

is evidently extending itself, particularly as regards the erection of villas, cottages, hunting-seats, gate-lodges, and other rural residences. To these the old English style is peculiarly well adapted. The leading feature of this style applied to cottages is the dispensing with unbroken lines. The house is composed of different parts, projecting at right angles from each other, with also a projecting porch, and the outshot octagonal windows commanding views in three different directions. It also sometimes exhibits an open rustic arcade along a portion of the front or back, which will be found useful and agreeable both in sultry and cold broken weather. It is not uncommon for a cottage of this kind to have on the ground-floor two parlours, communicating by folding-doors, 14 feet by 12 each, and 10 feet in height; a kitchen and scullery, with a porch 7 feet by 5 feet 6 inches, opening to a staircase 17 feet 6 inches by 8 feet, with three rooms above. The gables are terminated with fineals and ornamental dressings to the doorways and windows, and handsome octagonal chimney-stacks. We offer a representation of a cottage in this elegant style in fig. 27.

Improvement is also shewn in the style of church-building, particularly in the northern part of the United Kingdom, where there was most room for it. Since the Reformation, churches have been built in Scotland with very little regard to elegance; and in the last century particularly, there flourished a style, the products of which are scarcely to be distinguished from barns and granaries. Within the last thirty years, very few ecclesiastical structures have been erected without an effort being made to unite some degree of taste with a regard for conveniency. A modest Gothic style has become very prevalent, which, though not always free from faults, is a surprising advance upon the homely edifices of the last century.

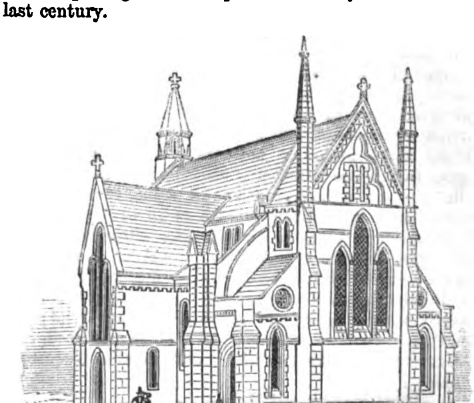


Fig. 28.

In fig. 28, a representation is given of one of these improved ecclesiastical structures, suitable for a rural scene, or any other situation in which economy of means requires to be consulted.

MODERN BRITISH ARCHITECTURE.

During the sixteenth century, as has been mentioned, an extraordinary effort was made in Italy to restore the purity of the ancient Roman or Romanised Grecian architecture; and in this attempt, Palladio was followed by the not less eminent Michael Angelo Buonarotti, who, at an advanced age, in 1546, undertook the continuation of the building of St Peter's at Rome, a work on which the greatest splendours of the Italian style are lavished. Into England, this revived taste for the Roman was introduced, at the beginning of the seventeenth century, by Inigo Jones, to whose contemptuous observations on the pointed style the term *Gothic* has been traced; and after his decease, the Roman, or, more properly, the Italianised Grecian, was perpetuated

on a scale still more extensive by Sir Christopher Wren. The edifices erected by this great master are characterised by the finest taste, and his spires in particular are models of elegance. The greatest work of Wren was St Paul's Cathedral in London, in which the Italian is seen in all its glory.

The eighteenth century was an era of decline in architectural taste. Every other style merged in that of a spiritless and often mean Græco-Italian, out of which the architects of the nineteenth century have apparently had a difficulty to emerge. Latterly, there has been a revival in England of a purer kind of Grecian, and also, as we have already said, of old English, and the Gothic or pointed style, and in most instances with good effect. It is only to be lamented that, by the manner in which state patronage is distributed in this branch of the fine arts, some of the largest and most expensive structures—Buckingham Palace and the National Gallery, for example—have been erected on the poorest conceptions of the Grecian style, and with a general effect far from pleasing. In Paris there now exist some modern structures after correct Grecian models, which cannot be too highly praised; we would, in particular, instance the building called the Madeleine, the Bourse, and the interior of the Church of St Genevieve. In England, besides a multitude of churches, the New Houses of Parliament present an instance of recurrence to the Gothic, being probably the largest edifice of that kind in the world.

Houses and Streets.

Till about the year 1820, the street-architecture of Britain was on a poor scale; the houses ranging evenly with each other, being plain stone or brick edifices of generally three stories in height, overtopped by a slanting and tasteless roof of slate or tile; in London, and some other places, the ugly tile roof was hid by a portion of the front wall carried upwards as a parapet. At the above period, a new era may be said to have begun in town-architecture, whereby the houses were built more in a bold continental style, in which the Græco-Italian was aimed at with more or less success; and latterly, this improved taste has altogether superseded the barren architecture prevalent during the reign of George III. According to this revived taste, the houses are now constructed of polished stone, or covered with a plaster to resemble that material; the doors and windows are enlarged and ornamented, the stories more spacious and lofty, and the roof is frequently

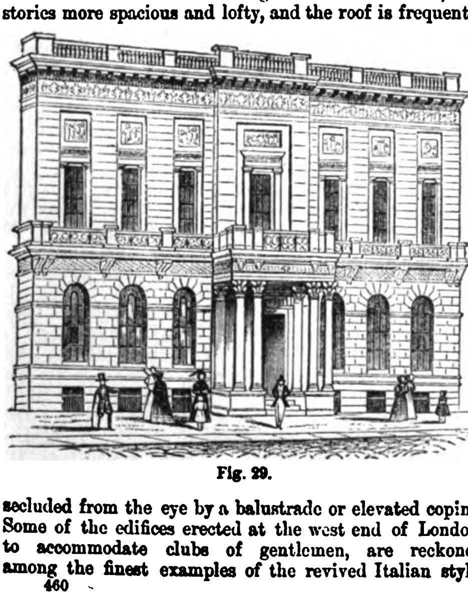


Fig. 29.

secluded from the eye by a balustrade or elevated coping. Some of the edifices erected at the west end of London, to accommodate clubs of gentlemen, are reckoned among the finest examples of the revived Italian style, and worthy of the best days of Palladio. The preceding cut (fig. 29) represents the front of the Oxford and Cambridge University Club-house, in Pall Mall, erected from a design of Mr Sydney Smirke, and distinguished for the richness of its cornice and entablature, as well as its generally imposing effect. The Carlton Club-house, in the same neighbourhood, is also by Mr Sydney Smirke, and is a very fine adaptation of the same style, upon a more magnificent scale.

The various changes effected in recent times in general street-architecture, are not more remarkable than those on the construction of shop-fronts, some of which now vie with the greatest efforts of the old Italian masters. A century ago, shop-fronts were little else than open booths, with an overhanging canopy. They afterwards were closed, and, as is well known, attempts were finally made to Grecianise them with pillars and pediments. The increasing rivalry and taste of shopkeepers, however, did not stop here; and in the present day, very extraordinary efforts are making to place shop-fronts among the works of classic architecture. The design, generally, is to supersede plain Grecian or Roman models by highly ornamental designs after the Italian style. The most favourable specimen we can present of this elaborate and splendid style of shop-frontage, is that observable at the corner of the Quadrant, Regent Street, London (fig. 30).

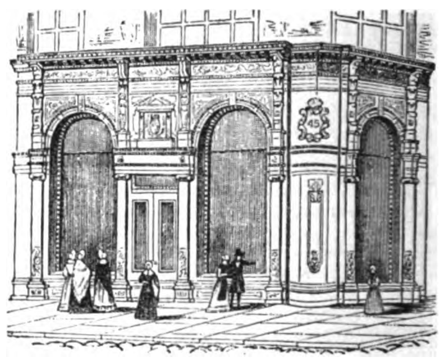


Fig. 30.

As an architectural composition, it possesses considerable merit, presenting, with the lightness of the plate-glass windows, the appearance of sufficient solidity and strength, and not looking as if likely to be crushed by the upper part of the edifice.

While recent edifices, with any pretensions to architectural effect, are thus, in themselves, superior to those of the last century, the fact that they are reproductions of classical or medieval designs, and that their merit is judged of by their correctness as copies, is certainly not satisfactory. It seems to indicate that architecture, as a fine art, is no longer among us a living art, as engineering is, which every day puts forth new developments under new exigencies, instead of seeking to revert to the past.

The constant recurrence to the past for the forms of ornamental architecture leads, besides, to endless incongruities. The ornaments, however beautiful in themselves, are often out of place, there being no real or apparent use for their being there. A pediment or portico, unless the termination of a real roof, and an integral part of the building, is a meaningless ornament, and is as inappropriate in Grecian as in any other style. The evil of a slavish adherence to classic models is seen in the case of windows. The invention of window-glass in the sixth century rendered a purely Greek building practically obsolete. The few windows of the ancients were placed high in the walls, and many chambers were lighted exclusively by torches. In some temples, the colonnade supporting the roof was open. Windows are now a grand feature in the building, for cupola-light is

not always attainable or always desirable; and windows, therefore, instead of being merely 'poked out,' should exhibit some distinctive characteristic of the order. The glass windows are not incongruous in themselves, being a modification of absolute necessity in the present age; but unluckily they are mere holes in the wall, with no more reference to the Grecian than to the Gothic style of architecture.

The Gothic, in like manner, becomes in our hands merely ridiculous. Baby-house towers and turrets—battlements where no battle can be waged—mock machicolations—niches in the walls for dolls instead of statues.

Amid this confusion of ideas and styles, Mr Fergusson (*Hand-book of Architecture*, London, 1855) points with satisfaction to the Crystal Palace at Sydenham, as at least one great building carried out wholly on a principle. 'No material is used in it which is not the best for its purpose; no constructive expedient employed, which is not absolutely essential; and it depends wholly for its effect on the arrangement of its parts and the display of its construction. . . . This, however, is only the second of a series. A third would probably as far surpass it, as it is beyond the first; and if the series were carried to a hundred, with more leisure and a higher aim, we might perhaps learn to despise many things we now so servilely copy, and might create a style surpassing anything that ever went before.' Such structures, however, from their ephemeral nature, are not suitable for the higher efforts of art. The iron-and-glass style, as it might be called, is chiefly valuable as a means of covering in a large space at a comparatively small cost. By the copious use of glass, and by taking skilful advantage of the rigidity of iron in its cast state, and of its tenacity as wrought iron (in forming *ties*), a firm and weather-tight fabric can be reared, with a smaller weight of materials than was ever dreamed of before.

MONUMENTAL COLUMNS.

The erection of triumphal or monumental columns was a favourite idea of the Romans. Augustus erected a column of white marble near the Temple of Saturn, in the Forum at Rome, as a centre whence the account of the miles began in the calculation of distances from the city. This celebrated column, which is still in existence,

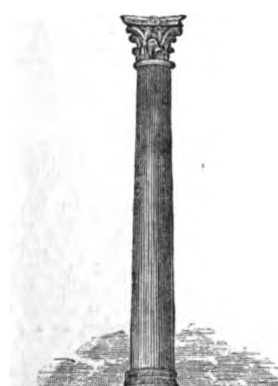


Fig. 31.—Pompey's Pillar.

is, however, not of great altitude. Among the principal triumphal columns of antiquity now remaining, is what is called the Column of Pompey, constructed of red granite, and situated on a rock, about a mile without the walls of Alexandria in Egypt. An inscription, now nearly effaced, seems to prove that it was erected in honour of the Emperor Diocletian by the then prefect of Egypt. The total height of this column is stated at 98 feet 9 inches, the shaft being 73 feet. The spectator can never be tired with admiring the beauty of its Corinthian capital, the length of the shaft, or the extraordinary simplicity of the pedestal.

The Trajan Column, which falls next to be mentioned, is one of the most celebrated monuments of antiquity. Its height, including the pedestal and statue, is 132 feet. This monumental column was erected in the centre of the Forum Trajani, and dedicated to the Emperor Trajan for his decisive victory over the Dacians, as is testified by the inscription on the pedestal. It is of the Doric order, and its shaft is constructed of thirty-four pieces of Greek marble, joined with cramps of bronze, and so curiously cemented as to appear but one entire stone. For elegance of proportion, beauty of style, and for simplicity and dexterity of sculpture, it is the finest in the world. The figures on the pedestal are master-pieces of Roman art. There are other columnar erections in Rome; one of which is the column of the Emperor Phocas, near the Temple of Concord; it is of Greek marble, fluted, and of the Corinthian order, 4 feet diameter, and 54 feet high, including the pedestal.

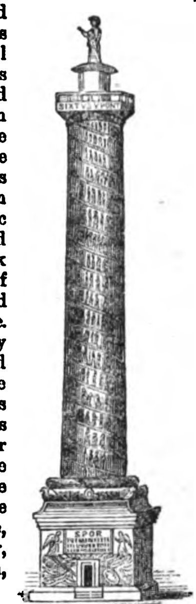


Fig. 32.—Trajan's Pillar.

The column which ornaments the British metropolis, better known as the Monument, was designed by Sir Christopher Wren, and erected by order of parliament, in memory of the burning of the city of London, anno 1666, in the very place where the fire began. This pillar was begun in 1671, and finished in 1677. It is of the Roman Doric order, fluted, 202 feet high from the ground, and 15 feet in diameter, of solid Portland stone, with a staircase in the middle, of black marble, containing 385 steps. The lowest part of the pedestal is 28 feet square, and its altitude 40 feet; the front being enriched with curious bass-reliefs. It has a balcony within thirty-two feet of the top, on which is placed a blazing urn of gilt brass.

The column in Phœnix Park, Dublin, differs from any other work of this description. It was erected in 1745. The pillar is formed of Portland stone, and is of the Corinthian order, fluted, and highly ornamented. The base and pedestal are 5 feet in height, the shaft and capital 20 feet, and the phœnix which surmounts the column 5 feet, so that the whole presents an object 30 feet high.

The Napoleon Column has justly been considered as the greatest ornament of the French capital. It stands in the Place Vendôme, and was erected to commemorate the successful result of Bonaparte's arms in the German campaign of 1805. Its total elevation is 135 feet, and the diameter of its shaft is 12 feet. It is in imitation of the Pillar of Trajan, and is built of stone, covered with bass-reliefs—representing the various victories of the French army—composed of the metal of 1200 pieces of cannon taken from the Russian and Austrian armies. The bronze employed in this monument was about 360,000 pounds-weight. The column is of the Doric order. The bass-reliefs of the pedestal represent the uniforms and weapons of the conquered legions. Above the pedestal are festoons of

oak, supported at the four angles by eagles, in bronze, each weighing 500 pounds. The bass-reliefs of the shaft pursue a spiral direction from the base to the capital, and display in chronological order the principal actions of the campaign, from the departure of the troops from Boulogne to the battle of Austerlitz. The figures are three feet high; their number is said to be 2000; and the length of the spiral band 840 feet. Above the capital is a gallery, which is approached by a winding staircase within, of 176 steps. The capital of the column is surmounted by an acroterium, upon which stands the statue of Napoleon, measuring 11 feet in height, and weighing 5012 pounds. The total expense of this sumptuous monument was 1,500,000 livres.

There are also several smaller columns, but of beautiful proportions, in various parts of England, in imitation of the above. A very common error is committed in the erection of monumental columns, by loading their summit with a clumsy mass of masonry, on which the statue is placed, and technically called an *acroterium*. The Melville monument at Edinburgh presents a notable instance of this kind of defect. If there must be an acroterium, it cannot be too modest in its proportions, or too little seen by the spectator.

THE PRACTICE OF ARCHITECTURE—CONSTRUCTION.

In erecting buildings, the first step to be taken is to select an appropriate site; after which, the designs have to be prepared, which is usually done at first in a sketchy manner, so as to be easily altered to suit the requirements of the party building. The sketches should comprise plans of all the stories, and elevations of all the parts, together with a perspective view, so that a more satisfactory idea may be formed of the actual appearance of the building when erected. The design being approved and determined upon, the 'working-drawings' have then to be made for the guidance of the contractors in estimating the cost of the erection, and of the workmen during its construction. The working-drawings are usually made to a large scale, and ought to represent, in due proportion, every portion of the work to be executed. Nothing should be left conjectural; every thing should be exhibited on the working-drawings, or described in the specification. The working-drawings consist of plans, sections, elevations, and detailed drawings. The plans, sections, and elevations are usually drawn to the same scale—never less than $\frac{1}{8}$th, and usually $\frac{1}{4}$th of an inch to one foot. The detailed drawings should be as much as possible drawn full size. The elevations are of various kinds—as *front*, *back*, or *end* elevation. They represent those portions of a building as they appear when viewed from points directly opposite—that is, without any perspective effect. The sections also vary in number, and are used to delineate the appearance of the structure as it would be if cut down from top to bottom in a direct line. As a plan shews the horizontal arrangement and connection of apartments, so sections do that of the vertical parts; as the height of the rooms, the position and arrangement of floors, roofs, partitions, &c. It is the architect's duty to prepare what is termed a *specification*. This requires to be very carefully drawn up, as it is the document which regulates the kinds and qualities of materials, and how they are to be used, and which defines exactly the duties of the builder. In large buildings, what are called *bills of quantities* are also drawn up, sometimes by the architect appointed to the works, sometimes by a disinterested surveyor. This document consists of a series of tables, in which the various measurements connected with the different departments are laid down; as the number of cubic feet of excavation required, the amount of brickwork, the surface of plastering, &c. This is handed to the party estimating, who affixes a price to each, and estimates accordingly. The architect usually receives, as an honorarium, a sum equal to 5 per cent. on the whole outlay. The construction of the building is intrusted to a builder, who is under the control and superintendence of the architect. All deviations from the specification are treated and allowed for as *extras* or *deductions;* these generally render the actual cost greater than the estimated, and are therefore to be avoided as much as possible, by thoroughly considering every point before the specification is drawn up. It is a good plan to insert a clause in the agreement, by which the builder executing the work agrees to undertake all extras at a certain rate.

In the construction of domestic buildings, certain points must be attended to, in order to attain stability, permanence, immunity from fire, and health. As to the questions of site and internal arrangements, so as to secure convenience and comfort, we refer the reader to the number on HOUSEHOLD HINTS, where suggestions of a practical character may be met with. Viewing it as a matter of some importance that a knowledge of what is requisite in house-building, to insure safety and health, should be more generally diffused than it apparently is now, we propose to devote the remainder of our present paper to a glance at the chief points—these being foundation, walls, floors, partitions, roofs, fire-proof construction. Our remarks will have a more particular reference to the styles of domestic construction usually adopted in England. They will, however, be easily applicable to other forms of structure.

As to the best method of preparing a site so as to secure a good and dry foundation, the reader will find some hints in our paper on THE HORSE, in the section on Stables. Fig. 33 shews the method of building the foundations; the wall rests on a series of *footings*, *b*, stability being secured by thus spreading out the bearings on which it rests. As a damp house will always be an unhealthy one, every care should be taken to prevent moisture gaining access to the walls. A proper treatment of the foundation will go far to effect this: filling in the trenches with concrete is a good plan.

Fig. 33.

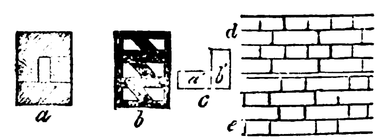


Fig. 34.

Another method, and one which, from its certainty, should be adopted where possible, is to raise the floor to such a height that the house must be approached by two steps at least.

Walls.—The important desideratum of dryness is attained also by the method of building *hollow walls*, now fast getting into use; which has the additional advantage of saving material. In fig. 34, we give various methods of building brick-walls hollow: *a* shews a section of a nine-inch wall, and *b* a nine-inch patent brick. In building brick-walls, there are two ways of setting the bricks, called old English and Flemish bond. When a brick is placed lengthways to the front, it is termed a *stretcher*, as *a'*; and a *header* when across the wall, as *b'* (*c*, fig. 34). In old English bond, which is the safest, a row of headers and a row of stretchers alternate, as *d*, fig. 34; in Flemish, a header and a stretcher alternate in the same row, as *e*, fig. 34. To secure what is called *bond* in brick-walls—that is, a thorough cohesion between the various parts—strips of sheet-iron, covered with tar, are built in as the work progresses. Wood bonding should seldom be used, because of its liability to decay. In carrying up brick-walls, care should be taken to see that the workmen do not build one part at a quicker rate than another: the whole should be carried up evenly, which will secure uniformity of settlement, and prevent cracking. When finished, the outer joints should be *pointed*—that is, well filled up with mortar; and as the work proceeds,

the brickwork should be *grouted*, or run in with liquid mortar. All openings for doors, windows, and fireplaces should be arched over. Where timber is used for lintels, it should be of the best description: English oak, or Baltic timber, is the best adapted for the purpose. All lintels should have as little bearing on the walls as possible, consistent with stability. Timber in walls is bad on account of its liability to decay. Stone-walls are usually constructed solid, but they may be made hollow with advantage, although this will be more difficult of execution than in brick. Where all the stones are squared and worked on the face, the wall is termed *ashlar;* where they are of irregular size, it is termed *rubble*.

Floors consist of three varieties: composite, stone or brick, and wood. For cottages, the ground-floors may be made very cheaply and efficiently, thus: lay evenly a concrete of broken brick and tar; upon this, spread a mixture composed of lime ashes and sand; when dry, if rubbed over with linseed-oil, it will have the appearance of stone. Stone-flags are generally used for the formation of kitchen and lobby floors. For the former, hollow bricks will be cheaper; and for the latter, encaustic tiles more elegant. Timber floors are generally constructed in one of two ways. The two methods are delineated in fig. 35, where A shews a *single*

A B

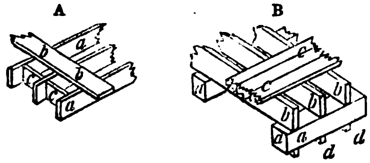


Fig. 35.

flooring, and B a *double*. In the former, the beams or joists, *a*, rest upon the walls at either end, and upon them the flooring-deals, *b*, *b*, are laid. The distance between the joists should not exceed 12 inches. Strength is obtained by having the joists thin and deep. For a distance of 12 feet from wall to wall, 8 inches deep by 3 thick will be found ample. When the bearing exceeds this, or even 8 feet, stays of thin pieces of wood, the same depth as the joists, may be inserted between the joists in a line, as at *c*, called *bridging*, which makes the floor firm and steady. A double floor consists of a series of *binding-joists*, *a*, *a*, resting on the wall, the distance between them being usually 6 feet; on these the *bridging-joists*, *b*, *b*, are laid, which, again, support the flooring-planks, *c*, *c*. The distance between the bridging-joists, *b*, *b*, is from 12 to 18 or 20 inches. For upper floors, the ceiling-joists of the room below are fixed on the under part of the binding-joists, *a*, *a*, as at *d*, *d*. A third kind of floor is sometimes employed in cases where the distance from wall to wall is great: it is termed a *framed floor*, and is much more complicated, the binding-joists resting upon heavy beams, termed *girders*, which rest on the walls. The introduction of iron beams, where extent of span is required, is now common, and is a very great improvement upon the old system. The use of iron beams is also now very common in the construction of fire-proof buildings, iron beams being placed at intervals of from 8 to 10 feet apart, in order to receive the brick arches, of which the fire-proof floors are composed. The passage of sound is prevented by *deafening*, which is effected by nailing strips of wood inside the joists, a few inches below the upper edge, and along the whole length; on these, pieces of board or lath are laid across, forming a species of floor, on which mortar is laid. This is called *pugging*, or counter-ceiling. In placing the ground-floors, care should be taken to have a due supply of air underneath the timbers; this will prevent, in great measure, the ravages of the dry-rot. In all cases, if possible, the ends of the joists should not be built in with the walls, but should rest in special apertures made therein for them. In some cases, iron shoes are built into the walls, in which the ends of the beams are placed. The ground-floor joists should rest on short piers carried up from the foundation—the object in all these cases being to have a free circulation of air around the timber, and to keep it as free as possible from damp. Where openings occur in the line of floor-timbers—as at fireplaces, staircases, &c.—an expedient known as a *trimmer* is used, exemplified in fig. 36. The wall opposite these openings being no longer

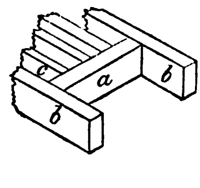


Fig. 36.

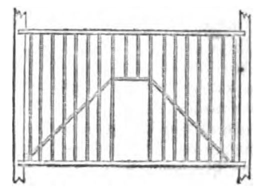


Fig. 37.

available as a bearing for the joists, the ends are supported by the *trimming-joist*, *a*, which is framed into the two joists, *b*, *b*. These joists are termed the carriage-beams, and have to be stronger than the ordinary joists, in proportion to the weight which the trimmer has to support.

Partitions require to be carefully attended to. The whole of the framework should be so arranged as to discharge all the weight upon the points of support, and relieve the floors, &c., below of all undue strain. In fig. 37, we give an illustration of a partition with a door in the centre.

Stair-steps, as generally arranged, are of two kinds—*flyers* and *winders*. In the former, all the steps are parallel, and lead from one story to another in two or more flights; resting-places being made at intervals by platforms, which serve also to change the direction. In the latter, the steps are narrower at one end than the other, and wind continually round a central shaft or cylinder. Parallel shaped steps are sometimes used in conjunction with the tapered ones. Staircases are generally more convenient when placed in the centre of the building; in this case, they are lighted by means of a sky-light above, which affords at the same time facilities for ventilation.

A wooden stair-step is composed of a *tread* and a *riser;* the tread is the flat surface on which the foot is placed, the riser is the vertical portion beneath the tread. The flight of steps are usually supported on stout *carriages*—lengths of timber in a raking position. The risers should be as near 6 inches high, and the tread 12 inches wide, as conveniency of space and situation will allow. The length of steps in private buildings varies from 2½ to 3½ feet.

Roofs, as constructed for modern private buildings, are an arrangement of timbers so disposed as to distribute the weight equally, and ultimately to deliver it on the walls or pillars intended for its support, avoiding all lateral strains calculated to thrust the walls out. In old buildings, so thick were the walls, and capable of resisting any outward thrust, that the *tie-beam* was unknown; so thin, however, are modern walls, that this avoiding of lateral thrust is specially to be attended to. The simplest form of roof is a *lean-to*, used where the back wall is higher than the other; a piece of timber is built in longitudinally along the top of the walls; the rafters are nailed to these at top and bottom, and the roof boarding on these. In a house with gable-ends, the simplest form of roof is a *ridge-pole*, or timber stretching from end to end of the house, and built in at the apex of the gable. The ends of the rafters abut against this at one end, and are nailed to *wall-plates*, formed of timber laid

on the walls. Where the building is of large dimensions, what are called *trusses* are used. These are placed at certain distances apart—say ten feet—and the rafters, &c., supported by them. Fig. 38 shews a form of truss:

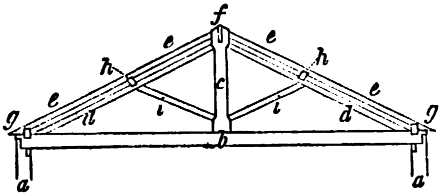


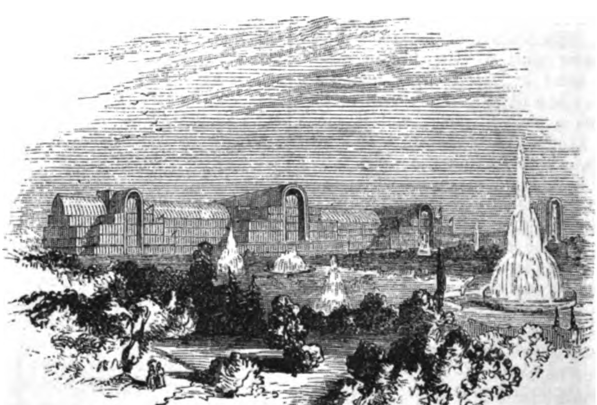
Fig. 38.

a, *a*, the walls; *b*, the tie-beam; *c*, the kingpost; *d*, *d*, the principal rafters, abutting at one end on the upper part of the kingpost, and at the lower on the end of the tie-beam. The ridge-pole, *f*, is let into the head of the kingpost, and stretches from truss to truss. The *common rafters*, *e*, *e*, are fastened to the ridge-pole at one end, and to the *poll-plate*, *g*, at the other. An intermediate support is also provided in the *purlins*, *h*, *h*, which are timbers let into the principal rafters, and stretching from truss to truss parallel to the ridge-pole; *i*, *i*, struts or stays.

Doors, Windows.—The width of entrance-doors varies from 2 feet 6 inches to 3 feet 8 inches; the height, 6 feet 6 inches, more generally 6 feet 8 inches. Internal doors are generally 2 feet 8 inches wide; closet-doors, 2 or 4 inches narrower. Internal doors are generally made with four panels. The moulding round the door-case is termed the *architrave*. Common doors, formed of a series of boards grooved together, and having cross strips nailed at the back, at top, bottom, and centre, are called *ledged*. *Windows* are of uniform breadth in a house; but those of each story differ in height from those above or below them. The height of a principal window should be $2\frac{1}{4}$ times the width; a second floor, $1\frac{3}{4}$ times; the third story, $1\frac{1}{2}$. For information on ventilation, construction of fireplaces, see number on HEATING.

Fire-proof Construction.—It has been truly remarked, that if our builders had been endeavouring to establish one mode of construction better than another for the facilitating of fires, they could scarcely have devised a better than the one now in such general use. The great point seems to be to use as much timber as possible, and to place it so that it will serve to convey the fire quickly from one place to another; hollow floors, ceilings, partitions, hollow spaces behind skirtings, all serve as chimneys—and chimneys themselves of the most inflammable materials; staircases fitted so as to burn with the greatest possible rapidity, beams thrust into chimney-flues, hearthstones resting on timber; the grossest carelessness everywhere observable. This is no exaggeration, but a simple statement of facts, and the wonder is not that so many, but that so few fires happen. If a system of solid, rather than honeycomb construction were adopted, we should have more safety from the ravages of fire. The construction of Scotch buildings contrasts favourably with the English mode. This solid system can be as cheaply obtained as the other, which is deprecated so much. By the use of hollow bricks, partitions can be made absolutely fire-proof; and by the adoption of the Parisian plan of forming floors and ceilings, fire, if breaking out in one apartment, can be confined thereto. The plan here alluded to may be briefly described as a system of forcing mortar between the joists of the floors with considerable pressure, so that the timber is, as it were, imbedded in a non-conducting material, which requires to be made almost red-hot before the timber can be touched. With our present system of plastering, a very moderate degree of heat serves to make the plaster peel off, exposing at once the wood, and opening up the series of hollow spaces before alluded to, which quicken the action of the fire. Wooden staircases, by the system of underlathing and mortaring, can also be made fire-proof. Space will not allow us to go further into this interesting subject.

Varieties of Domestic Structures.—Throughout England, the houses are generally constructed so that each has a separate entrance, or is self-contained, as it is called. In Scotland, town-houses are generally arranged in 'flats'—the first story only being self-contained, and the suits of rooms on the several stories above forming separate dwellings, with entrances from a common-stair. This plan of constructing houses is well adapted for the labouring-classes, as the ground-rent and other expenses are distributed over a greater number of tenants. For various hints of importance to building capitalists on this subject, see a pamphlet by Mr William Chambers. This work contains also some useful remarks on dwelling-places for the labouring-classes, a subject which occupies so much at present the attention of philanthropists.



Crystal Palace—Sydenham.

WARMING, VENTILATION, LIGHTING.

WARMING.

THE average temperature of the human body * is from 98° to 100°; and whether the individual be exposed to a tropical or to an arctic climate, his blood never rises above or falls below the medium more than one or two degrees, whatever his feelings of heat or cold may be. It seems as if this amount of heat, and no other, were consistent with the existence of warm-blooded animals; for if by any means the temperature of an animal's body is reduced below the above limit, its vital action declines, and soon comes to a stand. In like manner, when heated seven or eight degrees above its usual warmth, the vitality is destroyed.

The temperature thus necessary for the life of the body, is maintained by the action of that life itself. Objects surrounding the body being in almost all cases colder than it, are constantly stealing part of its warmth; but within the system there is an incessant process of combustion going on, producing fresh heat, exactly as the fire in a grate does. When the heat thus generated is not dissipated fast enough, so that the body tends to become warmer than the due degree, the accumulation finds vent in perspiration, the evaporation of which carries off the excess (see NATURAL PHILOSOPHY). In general, however, the tendency is the other way; the heat of the body, if allowed freely to escape, would be dissipated faster than it is produced; and hence arises the necessity of clothing, houses, and other means of retarding its escape. The lower animals are in general provided by nature with coverings for this purpose, according to the requirements of the climate in which they live. Man is left to the exercise of his inventive faculties to provide clothing and shelter for himself. In the lower animals, too, the heat-producing function is more active than in man. At least, this is true of civilised man; for there can be no doubt that the naked and painted savages that inhabited these islands 2000 years ago had a power of resisting cold unknown to us their descendants. In this respect, at least, the race has degenerated. At the present day, in fact, the people that inhabit Tierra del Fuego and the west coast of Patagonia, though living in a climate in which there is hardly a day without rain, snow, or sleet, and not a month without frost, have no covering except a scrap of hide tied to the waist. Even in civilised communities, those that lead a life of activity in the open air require far less protection from the cold than those that live indoors. There is, besides, the greatest difference in this respect between individuals, though placed in exactly similar circumstances—a difference intimately connected with the soundness of the digestion and other nutritive processes. From not recognising this constitutional difference, serious errors are committed. The cold-blooded are accused by the more hardy—and are apt to accuse themselves—of effeminacy, as if they were merely shrinking from a disagreeable sensation. But the truth is, that the sensation of cold on the surface, which merely makes the skin of the strong man smart, and for the rest only stimulates the system to produce more heat than ever, quickly lowers the temperature of the less vigorous to a greater depth, and deprives the vital powers of the ability to react.

* The average temperature of the other mammalia is almost the same as in man; that of birds is 106°; reptiles, fishes, insects, &c., differ little in warmth from the air or water in which they live.

It is well, no doubt, for even the weak to encounter cold, provided they keep in motion. But to encounter cold and overcome it, is a very different thing from passively suffering cold. To allow the body to continue depressed in temperature beyond the natural state, instead of hardening, infallibly weakens its vitality, and sows the seeds of disease. And that this error is committed on a vast scale, in Britain more especially, is apparent enough. The feelings of buoyancy which most persons in tolerable health experience during a clear frosty day, have led to a general belief in the peculiar healthiness of cold weather. But the statistics of death and disease tell a different tale. The reports of the registrar-general shew that, exactly as the thermometer sinks, the rate of mortality rises, and certain diseases of the most fatal kind become more prevalent; the vitality, in short, of the community decreases as the warmth of the atmosphere decreases. Whatever comfort, then, or temporary benefit the more vigorous individuals may derive from cold, it is clear that the community at large suffer from it—suffer seriously, both in comfort and health. We believe it to be an established fact, that the means generally taken to arrest the waste of heat from our bodies, or to supplement it, are, for the majority of men and women, insufficient, or injudiciously managed. This is a matter of literally 'vital' moment to one and all. The economy of heat is a primary element in the art of living in health and comfort; and no 'knowledge of common things' that we can think of, can surpass in importance a right understanding of the principles and facts on which that art rests.

We have as yet spoken of arresting the dissipation of the natural heat by clothing and shelter; and this, among some nations, is made to suffice. Where fuel is scarce, the resource against the cold of winter is thick clothing indoors as well as out. This is said to be the regular practice in China; and even in the south of Europe, fires are dispensed with in weather when we should think them absolutely necessary, and additional wrappings are considered as appropriate while sitting in the house, as in the open air. But wherever fuel can be had, it is always preferred to wear within doors much the same clothing in winter as in summer, and to keep the apartments nearly at summer temperature by artificial heat. It is this special branch of the subject, namely, the artificial warming of apartments, that we are at present to consider; that of Clothing will be treated in a subsequent number (see also PRESERVATION OF HEALTH).

In order to regulate temperature, we must first know the nature of heat—how it is produced, and what laws it follows. This forms a branch of the science of Physics, and has been briefly treated in NATURAL PHILOSOPHY. But for the better understanding of the present subject, it may be well to say something more here of

Combustion,

Which is the chief source of artificial heat. Combustion consists in the rapid union of the oxygen of the air with some substance for which it has a strong chemical attraction, and which is called a combustible or fuel. All chemical combination produces heat; but it is only called combustion when the heat is so intense as to produce light. The cheapest combustibles or fuels are coal, wood, peat, coke, and charcoal, which consist chiefly of two simple bodies or elements, carbon and hydrogen (see CHEMISTRY). Before oxygen will unite with the combustible, the latter must be heated to a high pitch; the combustion once begun in one part of the fuel, is then

sufficient to keep the rest at the combining temperature, provided the heat is not too rapidly dissipated. One piece of fuel will seldom keep alight alone; a number of pieces require to be burned together, in order to keep one another warm. To blow cold air rashly into a weak fire, puts it out, by suddenly cooling the coal below the combining point. A cold poker held near the flame of a candle will extinguish it; and a fire, on the other hand, burns much better when surrounded by bricks, than by metal. The bricks act like clothing, and keep in the heat of the coals; the iron being a good conductor, runs away with the heat as fast as it is generated, and passes it into the wall, making the coals that touch it dull and black.

Products of Combustion.—The carbon of the fuel unites with $2\frac{2}{3}$ times its weight of oxygen, forming carbonic acid gas, and the hydrogen with 8 times its weight, forming water in the state of vapour or steam. For the complete combustion of a pound of coals of average quality, about 230 cubic feet of air are required; of which some 46 feet are oxygen, and the rest nitrogen, which takes no part in the combustion. This nitrogen mingles with the carbonic acid and vapour before mentioned, and the whole ascend from the fire in the form of a heated gaseous current, which, when the combustion is complete, is colourless as common air. Were the fuel composed of carbon and hydrogen alone, these would be the only products of perfect combustion; *ashes* arise from earthy incombustible substances in the fuel, which lessen its value. If the fuel contain water, the water is driven off in steam, and carries away a great deal of the heat of the fire in a latent form. From this cause, green wood gives little heat; and coals when wetted give less than the same quantity burnt dry.

The really valuable product of combustion is the heat evolved. There are various ways of measuring its amount—as by the quantity of ice it melts, or the number of degrees to which it heats a certain quantity of water. Thus, it is found that the burning of one pound of good coal melts 90 pounds of ice; of coke, 84 pounds; of wood, 32 pounds; of charcoal of wood, 95 pounds; of peat, 19 pounds. In speaking of the heating effects of combustion, it is specially necessary to bear in mind the different capacities of bodies for heat, or their *specific heat.* Water, for instance, has great capacity for heat, or is very difficult to warm. The same amount of heat that raises the temperature of a cubic foot of water 1°, will heat 2850 cubic feet of air to the same extent.

The combustion of fuel is seldom perfect, except in the case of coke, wood-charcoal, and anthracite coal, which are composed of carbon without hydrogen. Common coal consists partly of carbon, and partly of bitumen or pitch. The bitumen also contains carbon, but in combination with the volatile gas, hydrogen; and when heated to a certain degree, it rises or distils off in vapour. If the heat is only about 600°, this vapour is thick and black, constituting *smoke*, and as it cools, it deposits *soot*, which is carbon in fine powder. A greater heat makes the carbon and hydrogen take another arrangement, and become carburetted hydrogen gas—common coal-gas—which is transparent like air, and does not deposit carbon when cold. It is this highly heated gas, combining with the oxygen of the atmosphere, that constitutes *flame.* The pitchy vapour rising from burning fuel is not hot enough to combine with oxygen, unless it come in contact with flame or hot coals. It thus appears that fuel which burns with flame has always more or less hydrogen in it; coke and charcoal, from which the gaseous part has been driven off, burn without flame.

We now proceed to consider the application of the heat thus generated to the warming of dwellings, keeping in view rather the illustration of the general principles that should guide every such application, than entering into constructive details of apparatus.

The great aim, it may be premised, in all plans of warming is, as it is expressed by Dr Arnott, '*to obtain everywhere on earth, at will, the temperature most congenial to the human constitution, and air as pure as blows on a hill-top.*' The obtaining of the desired temperature would be comparatively easy by itself; the difficulty lies in combining warmth with pure air. The various plans hitherto tried may be classed under the four heads of—The Open Fire, Stoves, Gas, Steam and Hot Water.

THE OPEN FIRE.

The first application of artificial warmth consisted, most likely, in lighting a fire of dried sticks and leaves in a grove, a cave, or other natural shelter. When tents or wigwams came to be erected, the fire would be lighted on the middle of the floor, with perhaps a hole in the roof for the smoke to escape by. This primitive arrangement may still be seen in some of the cabins of Ireland and the Scottish Highlands. The Romans warmed their apartments chiefly by portable stoves or chafing-dishes, without any regular exit for the smoke and fumes; and a brasier of charcoal is still the chief means of lighting sitting-rooms in Spain and Italy, which are in general without chimneys. As late as the fourteenth century, the hearth in Britain continued to be in the middle of the apartment, and the smoke escaped by an opening in the roof, called the louvre (Fr. *l'ouvert*). At last, the fire was placed at the side, in a sort of apartment formed by two projections, within which were placed seats where the warmth might be enjoyed. This recess came gradually to be built in the thickness of the wall, and was thus transformed into the modern chimney.

It is scarcely necessary to remark, that the mode of heating apartments now most prevalent in Britain is by a fire of coal placed in a grate, having a chimney above, through which the vaporised products of the fuel are carried off. Of one class of results from this mode, there can be no doubt. The fire glowing in its appropriate receptacle has an air of cheerfulness and comfort, causing the domestic group to cluster around it with that feeling of satisfaction which makes an Englishman regard his fireside as amongst the most precious things connected with his existence. But while the common open fire is almost an object of worship amongst us, on account of its pleasant look and power of concentrating the whole family in one social circle, it is not unattended with certain drawbacks and disadvantages: the greatest of these is the uneconomical use which it makes of fuel. About one-half of the heat produced by a common fire ascends with the smoke; the black part of the smoke itself being an unconsumed part of the fuel. Finally, about a fourth of the heat which is radiated into the apartment is, in ordinary circumstances, carried into the chimney between the fire and the mantelpiece, and thus lost. It is calculated by Dr Arnott, that only about one-eighth part of the heat-producing power of the fuel used in common fires is realised, all the rest being dissipated into the surrounding atmosphere. It is also unquestionable that often a common fire is found to give a partial kind of warmth, heating the side of our persons next to it, but leaving the rest cold; and that it produces draughts into our rooms which are anything but safe or agreeable. Notwithstanding these and other acknowledged evils, the open fire continues to hold its place, partly perhaps from prejudice, partly from real points of superiority over other methods as yet practised; and the object of late has been, not so much to do it away, as to improve it.

Grates.—One improvement consists in diminishing the quantity of metal in immediate contact with the fuel, and forming the back and sides of the grate of fire-bricks. For the reason given above, this renders the combustion more complete and the fire far hotter; and therefore the same quantity of fuel not only produces

more heat, but throws a greater proportion of that heat out into the room, and less up the flue and through the wall, than when it is surrounded by a mass of iron; for radiation depends more upon the intensity of heat than upon its quantity.

Another point deserving attention is the shape given to the chimney-mouth, or recess above the grate. When the sides are square with the back, none of the heat falling on them is given out again into the room. With a view, therefore, to throw out the heat better, the sides, or *covings*, as they are called, are inclined to the back at an angle of about 130°; and sometimes they are made curved and of polished metal, in order that they may reflect the heat without absorbing it. It is questionable if simple brick slabs, placed at the proper angle, do not throw out more heat than the most splendid polished metal plates. For though the bricks do not reflect the rays of the fire, they become heated themselves, and then radiate their heat into the room. Plates of rough metal absorb the heat that falls upon them as the brick does; but being good conductors, the heat passes through them into the wall, and thus they never become hot enough to radiate sensibly.

Much also depends upon the shape of the fire-box, or grate itself. To see the importance of this, it is necessary to attend carefully to the exact way in which an open fire heats a room. It does so almost entirely by the rays of heat that it throws out; and these rays do not warm the air directly; they pass through it like light through glass, just as the hottest rays of the sun pass through the upper atmosphere, leaving it cold enough to freeze mercury. It is only when the rays of the fire fall on the floor, furniture, and walls of the room, that they give out their heat; and it is by coming in contact with these solid heated bodies that the air is gradually warmed. We may thus see the necessity of having a fire lighted and burning brightly for a considerable time before the hour when the apartment is expected to be comfortable.

The law that radiant heat neither affects nor is affected by the surrounding air, also explains the fact that an apartment may feel very cold, though the air in it be at high summer heat. A church or other massive stone building in frosty weather may be filled with heated air, and yet retain its chilling effect for many hours. The warmth of the living body is lost in two ways: the film of colder air that touches it receives part of its heat by conduction, and rising up makes room for another film to do the same; a moderately heated body in cooling, is robbed of about half its heat in this way. The other half is given off in rays, which pass through the air and impinge upon the objects around. These objects are radiating back heat in return; but their temperature being low, the return is small, and the warmer body is colder by the difference. Hence we are chilled by a cold wall or a cold window without touching it, and though the air between us and it may be at 70°.—To return to the shape of the grate.

The chief object is to present as large a surface as possible of glowing fire to the front. With this view, the grate is made long and deep, in proportion to its width from front to back. This principle, however, is carried too far in many grates. The stratum of fuel is too thin (see p. 66) to burn perfectly, especially in the narrow angles at the sides, where the coals seldom get to a red heat, and are only warm enough to distil away in smoke. Such fires are constantly going out, and are further from being economical than a square box.

The practice recently come into vogue of placing grates almost on a level with the floor, has been demonstrated by Dr Arnott to be a complete mistake. It is as the winter, contrasted with the summer sun.

The chimney-throat, instead of a gulf drawing in a constant wide current of the warm air of the room, and causing draughts from windows and doors towards the fireplace, should just be sufficient to admit the burnt gases and smoke that come directly from the fire, and no more. This is the object of the movable plate in what are called *register-grates*.

It would be endless to attempt to enumerate the various forms of grate constructed, with more or less success, on the above principles. We shall content ourselves with a notice of the recent invention of Dr Arnott, to whom the subject of warming apartments is more indebted than to any individual since the days of Count Rumford. It comes nearer to the idea of perfection in an open fireplace than any previous contrivance. Its peculiar advantages will be understood from the following description:

Arnott's Smokeless Grate.—ab, ef, represent the front bars of a grate in a chimney of the usual construction, *rswu*.

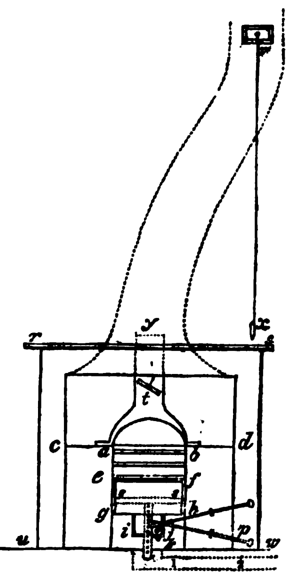


Fig. 1.

The grate has no bottom, and below it is an iron box, open only at top, into which the charge of coal for the day—from twenty to thirty pounds—is put. Any kind of coke or coal may be used. To light the fire, the usual quantity of wood is laid on the surface of the fresh coal at *ef*, and a thickness of three or four inches of cinders or coked coal, left from the fire of the preceding day, is laid over all. 'The wood being then lighted, very rapidly ignites the cinder above, and at the same time the pitchy vapour from the fresh coal below, rises through the wood-flame and cinders, and becomes heated sufficiently itself to become flame, and so to augment the blaze. When the cinder is once fairly ignited, all the bitumen rising through it afterwards burns, and the fire remains smokeless.'

As there is no supply of air but through the bars in front, the box being close underneath, the fire must be gradually raised up as the combustion goes on; and this is effected by having a false bottom, *ss*, in the box, which can be moved like a piston by means of a rod. The rod has notches in it, and, by means of the poker used as a lever, can be raised up and then retained at any height by a ratchet-catch. When the piston comes level with the bottom bar of the grate, the coals may be replenished while the fire is burning, by pushing in a flat shovel over the piston, so as to form a temporary bottom to the grate, and support the fire, while the piston is allowed to descend to the bottom. The shovel is then raised up a little in front, or a part of the upper edge of the box is made to fold down, and fresh coals are shot into the box;

on which the shovel is withdrawn, and the combustion goes on as before.

'A remarkable and very valuable quality of this fire is, its tenacity of life, so to speak, or its little tendency to be extinguished.' Even after it sinks below the level of the box, it does not go out, but continues to smoulder slowly for a whole day or night, and is ready to burn up actively when the piston is raised.

'In certain cases, as during long nights, it may be desirable to insure the maintenance of the slow combustion with rather more activity, and for this purpose there is a slide in a small door at the bottom of the coal-box, by which a graduated admission of air may be allowed. That door itself is opened quite before lighting the fire, to allow of the removal of the coal-dust or ash which, during the preceding day, has fallen down past the edge of the piston.'

Another peculiarity of the Arnott grate is the means taken to diminish the proportion of the heat usually carried up the chimney. Of the thick column of smoke that issues from a common chimney-can, only a small fraction is true smoke or burned air; the rest consists of the warmest air of the room, which becomes mixed with the true smoke in the large space usually left between the top of the fire and the throat of the chimney. 'The whole of the air so contaminated, and which may be in volume twenty, fifty, or even a hundred times greater than that of the true smoke, or burned air, is then all called smoke, and must all be allowed to ascend away from the room that none of the true smoke may remain. It is evident, then, that if a cover or hood of metal be placed over a fire, as represented by the letters *yab* in the diagram—or if, which is better, the space over the fire be equally contracted by brickwork, so as to prevent the diffusion of the true smoke, or the entrance of pure air from around to mix with it, except just what is necessary to burn the inflammable gases which rise with the true smoke—there will be a great economy. This is done in the new fireplace, with a saving of from one-third to one-half of the fuel required to maintain a desired temperature. In a room, the three dimensions of which are fifteen feet, thirteen feet and a half, and twelve feet, with two large windows, the coal burned to maintain a temperature of 65° in cold winter days has been eighteen pounds for nineteen hours, or less than a pound per hour.'

The hood is furnished with a throttle-valve or damper, *t*, having an external index, shewing its position, so as to give complete control over the current. The provision made for ventilation in this fireplace will be considered in another part of the paper.*

Even in this, perhaps the most economical form of open fire yet contrived, there is still great waste of the heat actually produced by the combustion. To say nothing of what passes by conduction from the fire itself into the wall, and is mostly lost; the quantity carried off in combination with the hot gases, though no more air is allowed to enter than is necessary for complete combustion, is still great. It deserves being noticed, that the proportion thus carried off is greatest in the case of fuel that burns with flame. Experiment shews that a fire of wood radiates one-quarter of its heat, the rest flying up; while the radiation from wood-charcoal is one-half of the whole heat produced. Every one has felt that a *blazing* fire has far less warming effect than a glowing one. Not that flame has not intense heat in it—more intense even than a glowing fire; but it gives it out only by contact, and not by radiation. It thus appears that any mode of heating that depends upon direct radiation, as the open fireplace chiefly does, necessarily involves great waste of fuel. This can be avoided only by applying the heat on a different principle, which consists in first making the fire heat certain apparatus with considerable surface, which then, by radiation and contact with the air of the apartment, diffuses its heat throughout it. This is the principle of the other methods of warming, which we now proceed to describe. The consideration of methods that combine the two principles, will come most conveniently last.

* Grates of this construction are manufactured by F. Edwards, Son, & Co., 42 Poland Street, Oxford Street, London, at from £2, 10s. to £7, 10s., according to the size of the apartment. With architectural decorations, in various styles, they cost £10–£30.

WARMING BY STOVES.

A *close stove* is simply an enclosure of metal, brick, or earthenware, which is heated by burning a fire within it, and then gives out its heat to the air by contact, and to surrounding objects by radiation. The simplest, and, so far as mere temperature is concerned, the most effective and economical of all warming arrangements, is what is called the Dutch stove; which is simply a hollow cylinder or other form of iron standing on the floor, close at top, and having bars near the bottom on which the fire rests. The door by which the coals are put in being kept shut, the air for combustion enters below the grate; and a pipe, issuing from near the top, carries the smoke into a flue in the wall. If this pipe is made long enough, by giving it, if necessary, one or more bends, the heated gases from the fire may be made to give out nearly all their heat into the metal before they enter the wall; and thus the whole heat of the combustion remains in the room.

The great objection to this form of stove is, that the metal is apt to become overheated, which not only gives rise to accidents, but has a hurtful effect upon the air. The exact nature of the change that highly heated metal produces upon air is not very well understood. It cannot be said to burn it, in the proper sense of the word, for none of its oxygen is abstracted, but it gives it a peculiar odour, which is both unpleasant and unwholesome. This is thought to arise in some measure at least from the hot iron burning the particles of dust that light on it, which particles consist of organic matter, such as wool, wood, &c.

Part at least of the unwholesomeness of air so heated arises from its excessive dryness; it parches and withers everything it touches, like the African simoom. It must not, however, be supposed that this is peculiar to air heated by contact with metal; *air suddenly heated is always unwholesomely dry.* This is an important point in regard to the subject of warming, and requires consideration. The relation of vapour to the air is fully explained in METEOROLOGY, which the reader is recommended to consult in connection with this subject. It may be stated shortly here, that a cubic foot of air, say at 32°, can contain a certain quantity of moisture and no more; but if heated to 80°, it is capable of containing *five* times as much, and has thus become *thirsty*, and drinks up moisture from everything that contains any. The heating of air, therefore, does not dry it, in the sense of taking moisture from it, it only renders it greedier of more; and this is equally true whether it is heated by a stove or an open fire. The chief difference is, that in the latter case the warming is more gradual, and no part of the air becomes very highly heated; while the air that touches a metal plate near redness is all at once rendered intensely thirsty, and before its fierceness is tempered by thoroughly mixing with the rest of the atmosphere of the room, must be highly pernicious. But whenever the temperature within doors is much higher than without, the air is in a too thirsty state, and parches the skin and lungs, unless means be taken to supply the necessary moisture. An evaporating pan or other contrivance is an essential part of warming apparatus; it is specially necessary to attend to this during east winds, which are generally too dry even at their natural temperature.

All improvements on this simple and rude form of stove aim at avoiding a high heat in the warming surface,

and this chiefly by lining the fire-box with brick, and enclosing it in several casings, so as to enlarge the heated surface. A general notion of these contrivances may be got from the annexed cut (fig. 2), representing the kind of stove called a *cockle*. The fire is burned in a small furnace within the inner case, and the air is warmed by circulating between the inner and outer cases. When placed in the apartment or hall to be warmed, the outer casing has perforations about the top for the issue of the warm air. For heating churches and similar buildings, the stove is placed in a separate furnace-room, and the warm air is conveyed to the different parts of the building in pipes or flues, while fresh air is drawn to the stove through a channel or culvert leading from outside the building to the openings in the outer casing, where the arrows are seen entering.

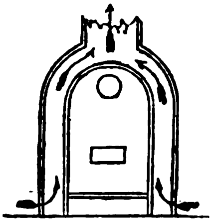


Fig. 2.

The stove invented by Dr Arnott is upon the same principle of an extensive and moderately warm heating surface. Under a sense of professional honour, Dr Arnott did not take out a patent for his stove. It was therefore made by many furnishing ironmongers in the metropolis and elsewhere, some of whom took out patents for what they considered as improvements upon it. No fewer than twelve patents were taken out in one year for modifications of this stove, *all of which Dr Arnott considered to be upon false principles*. The consequence has been, that many Arnott stoves, which had been introduced into houses, have been given up on account of the inconvenience felt from the species of heat which they generated. It is also, however, to be observed that the stove, made even upon the most approved principles, requires certain adjuncts and conditions in order to operate healthfully and agreeably.

The accompanying figure represents the Arnott stove in the most improved form given to it by the inventor.

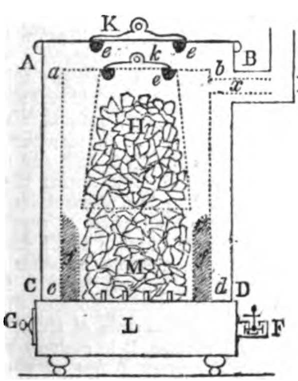


Fig. 3.

We give the description in his own words. 'The complete self-regulating stove may indeed be considered as a close stove, with an external case, and certain additions and modifications now to be described. The dotted lines and small letters mark the internal stove, and the entire lines, the external case or covering. The letters ABCD mark the external case, which prevents the intense heat of the inner stove, *abcd*, from damaging the air of the room. F is the regulating-valve, for admitting the air to feed the fire. It may be placed near the ashpit door, or wherever more convenient. The letters *ff* mark the fire-brick lining of the fire-box or grate, which prevents such cooling of the ignited mass as might interfere with the steady combustion. H is a hopper, or receptacle with open mouth below, suspended above the fire like a bell, to hold a sufficient charge of coal for twenty-four hours or more, which coal always falls down of itself, as that below it in the fire-box is consumed. The hopper may at any time be refilled with coal from above, through the lid, *k*, of the hopper, and the other lid, K, of the outer case. These lids are rendered nearly air-tight by sand-joints; that is, by their outer edges or circumference being turned down, and made to dip into grooves filled with sand, as at *e*, *e*. The burned air or smoke from the fire, M, rises up in the space between the hopper and the inner stove-case, to pass away by the internal flue, *x*, into the other flue, X, of the outer case. L is the ashpit under the fire-bars. G is the ashpit door, which must be carefully fitted to shut in an air-tight manner, by grinding its face or otherwise. M is the coal intensely ignited below where the fresh air maintains combustion, but colder gradually as it is further up. Only the coal in the fire-grate below, where the fresh air has access to it through the fire-bars, can be in a state of active combustion.' The self-regulating valve above mentioned is an ingenious contrivance by which the passage for the air is rendered narrower according to the force of the draught. Dr Arnott describes various other plans of effecting the self-regulation of the combustion.

For sixteen years, Dr Arnott has had his own dining-room warmed by such a stove. The fire in winter is never extinguished, and a uniform temperature of from 60° to 63° is maintained by consuming at the rate of about a ton of anthracite in six months.

A drawer inserted into the heated chamber of the stove would serve for cooking meat, and a pot for boiling might be placed upon the fire-box; it is therefore, as the inventor remarks, peculiarly the *poor man's* stove. Or, by making the space between the two casings water-tight, a *water-stove* is produced, which, besides securing a regulated heat, offers many other conveniences.

In Germany and other northern countries of Europe, the stoves are usually built of brick, covered with porcelain. They are of the size of a large and very high chest of drawers, and usually stand in a corner of the room. The fire is burned in a furnace near the bottom, and the heated smoke is made repeatedly to traverse the structure from side to side, along a winding passage, before it reaches the top, where a pipe conveys it, now comparatively cold, into a flue in the wall. The heated mass of brick continues to warm the room long after the fuel is burned. It is generally sufficient, to warm the stove once a day. The same quantity of wood burned in an open grate, would be consumed in an hour, and would hardly be felt.

Open-fire Stoves.—As a specimen of the numerous plans for combining the advantages of the stove and the open fire, we may take Sylvester's stove or grate, which is thus described in Ronalds and Richardson's *Technology:* 'The fuel is placed upon a grate, the bars of which are even with the floor of the room. The sides and top of these stoves are constructed of double casings of iron, and in the sides a series of vertical plates, parallel with the front facing, are included in the interior, which collect, by conduction, a great portion of the heat generated from the fire—the mass of metal of which these are composed being so proportioned to the fuel consumed, that the whole can never rise above the temperature of 212° Fahrenheit under any circumstances. The sides and top of the stove are thus converted into a hot chamber, offering an extensive surface of heated metal; at the bottom, by an opening in the ornamental part, the air is allowed to enter, and rises as it becomes warmed, traversing in its ascent the different compartments formed by the hot parallel plates, and is allowed to escape at the top by some similar opening into the room.' The Sylvester stove can either be placed in an ordinary chimney

recess, or be made to stand ornamentally forward into the room. The feeding-draught may be either taken directly from the apartment, or brought by flues from the outside of the building.

The idea of having an air-chamber behind and around the fireplace, from which warm air would issue into the room, thus saving part at least of the vast amount of heat that is lost by passing through the wall, is not new, having been put in practice by the Cardinal Polignac in the beginning of last century. But the way to carry the principle out to the full would be to have the open fireplace in a pier of masonry standing isolated from the wall, like a German porcelain stove. A very small fire would keep the whole mass mildly heated. The pier could receive any shape, so as to give it architectural effect; and it might either terminate in the room—the smoke, after parting with most of its heat, being conducted by a pipe into the wall—or it might be continued into the story above, where its heat would still be sufficient to warm a bedroom. An Arnott smokeless grate, set in the pedestal of an ornamental column, which might either stand in front of the wall or in a niche in its depth, might be made the *beau-idéal* of comfort, economy, and elegance.

WARMING BY GAS.

A prejudice arose against gas as a medium of heat, from the first attempts to employ it being made in an unskilful way. But when care is taken to carry off the products of combustion by a pipe, and to prevent overheating, gas-stoves will be found economical and pleasant, and capable of being used in situations where a common stove is inadmissible.

In stoves, gas should always be burnt with the Bunsen burner, which is generally employed by chemists when they make use of gas for heating purposes. It consists of a small brass cylinder, or chimney, set over the gas-jet, like the glass of an argand lamp, with openings near the bottom to allow air to enter. The gas being admitted into this before lighting, mixes with the air, and when lighted at the top, burns with a pale-blue flame. The most complete combustion, and the greatest heat is obtained in this way. We can speak from experience of the porcelain gas-stoves fitted up on this principle by Mr Millar of St Andrew Street, Edinburgh. Smoke, properly so called, there is none. Still it must not be forgot that there is burnt air—a cubic foot of carbonic acid, besides a quantity of watery vapour, for every cubic foot of gas used; and therefore, even with the Bunsen burner, these gaseous products should, wherever it is possible, be conducted away.

A pleasant and very serviceable gas-stove might be constructed by making the casing double, to contain water. It has been ascertained that a gallon of water may be brought to the boiling-point in twenty minutes

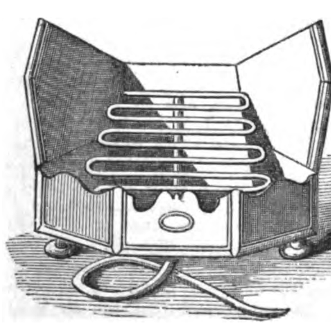


Fig. 4.

by burning 4 cubic feet of gas, which, at 4s. 6d. per 1000 feet, costs only $\frac{22}{100}$ of 1d. The cost of doing the same by a newly lighted coal-fire is more than threefold.

Attempts have been made to combine the appearance of an open fire with heating by gas. Fig. 4 represents such a contrivance. As flame gives out very little radiant heat, the coils of punctured tube are covered with a layer of asbestos shavings, which sparkle and glow in the ignited gas. In other gas-grates, the gas is burned in conjunction with coke.

STEAM AND HOT WATER.

The immediate warming agent in these two methods is the same as in Arnott's and other low-temperature stoves—namely, an extensive metallic surface moderately heated; but instead of heating these surfaces by direct contact with the fire, the heat is first communicated to water or steam, and thence to the metal of a system of pipes. This affords great facility in distributing the heat at will over all parts of a building; and these methods are peculiarly adapted to factories, workshops, and other large establishments. Other advantages are—freedom from dust, and from all risk of overheating and ignition.

Steam.—Steam-warming is generally adopted in establishments where steam-power is used, as the same boiler and furnace serve both purposes. When steam enters a cold vessel, it is condensed into water, and, at the same time, gives out its latent heat till the vessel is raised to 212°, when the condensation ceases. The condensing vessel is usually a cast-iron pipe placed round the wall of the apartment near the floor. In admitting fresh air into the room, it may be made to pass over this pipe, and thus be warmed. The steam is conducted from the boiler by a smaller tube, which may be covered with list or other material, to prevent all condensation by the way; and the admission of the steam is regulated by a cock within the apartment, means being provided for allowing the air to escape. Where a pipe cannot be laid round the room, a coil of pipe may be formed, or the steam may be admitted into a large vessel or into a hollow statue, forming a steam-stove. Allowance must be made for the expansion of the tubes by heat; and they are so arranged that the condensed water is conveyed back to the boiler. One round of iron pipe, of 4 inches diameter, is quite sufficient to warm each of the large apartments or stories of the printing-office from which the present work issues.

There can be no proper comparison between this plan of heating and that of common fireplaces. Coal-fires cannot warm the air in large workshops; the heat is confined to their own immediate neighbourhood; hence the workmen are often obliged to draw near the grate to warm themselves. According to the plan here adopted, every part of the house is equally heated, and the whole of the workmen are as comfortable during the hardest frosts as if they were working in a pleasant summer day. It is difficult to estimate the expense of supplying the heat, seeing that the steam happens to be drawn from a boiler which is always in operation for other purposes. Excellent, however, as the process is, it is for many reasons unsuited to private dwelling-houses.

In calculating how much surface of steam-pipe will be sufficient to warm a room, it is customary to allow about 1 foot square for every 6 feet of single glass window, of usual thickness; as much for every 120 feet of wall, roof, and ceiling, of ordinary material and thickness; and as much for every 6 cubic feet of hot air escaping per minute as ventilation, and replaced by cold air.

Hot Water.—Hot-water apparatus was applied as early as 1777 by M. Bonnemain, in Paris, to warm the hot-houses at the Jardin des Plantes, as well as for the artificial hatching of chickens. It was first introduced into England by the Marquis de Chabannes in 1816, and is now used in many large buildings. It is more economical than steam, except where a steam-boiler is required for machinery; and from this and other advantages, it is generally preferred to steam-apparatus. One of these advantages is, that the heat begins to be

distributed, in some degree, as soon as the fire is lighted, while with steam-apparatus the whole of the water must be at boiling-heat before any steam enters the pipes.

There are two kinds of hot-water apparatus—high-pressure, and low-pressure. In the first, the water is confined, and can be heated to any degree; in the other, it is open to the air, and cannot be heated above 212°.

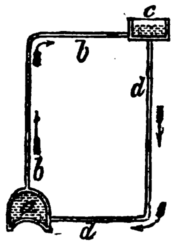


Fig. 5.

Fig. 5 will explain the way in which water is made to carry the heat of a furnace to any part of a building. *a* is a boiler, from the top of which a tube issues, and, after circulating through the building, re-enters near the bottom. At the top of the circuit there is a funnel, or a small cistern, *c*, by which the tubes and boiler may be kept full. When the fire is lighted at the bottom of the boiler, the heated portion of water, being lighter than the rest, rises towards the top through the tube, *bb*, while the colder water from *dd* flows in to take its place. The tube is made to traverse the apartments to be warmed, where it gives out its heat to the air; the returning portion of the pipe is thus always colder, and therefore heavier than the other, so that the circulation is constantly kept up. The warming surface is increased, wherever it is necessary, by coiling the pipe, or by making expansions upon it of various forms, so as to constitute water-stoves.

To avoid the necessity of so large a surface, and such a mass of water as is required at the low temperature the water attains in the pipes of this kind of apparatus, Mr Perkins introduced the high-pressure system. In this the pipe is made comparatively small, but very strong, and is formed into an endless circuit cut off from the atmosphere. The water is heated by making a number of coils of the pipe itself pass through the furnace; and as the whole circuit forms a shut vessel as it were, the temperature may be raised to 300° and upwards, according to the strength of the pipes. This high temperature causes a rapid circulation. A compendious and readily understood specimen of the apparatus, calculated for a house of three stories, is presented in the accompanying engraving. In filling the tube with water, which enters at *b*, care is taken to expel all the air; and at *a* there is an expansion of the tube, equal to 15 or 20 per cent. of the capacity of the whole, which is left empty both of water and air, to allow for the expansion of the water when heated. The arrangement of the pipe may be various: the plan generally followed is to place a considerable coil of it within a pedestal or bunker, with open trellis-work in front, in a convenient part of the room. It may also be made to wind round the room, behind the skirting-board, which, being perforated with holes, will allow of the entrance of the warmed air.

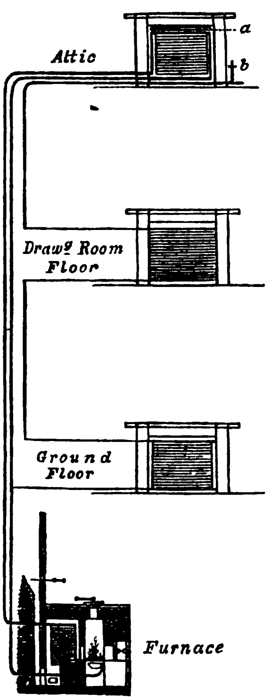


Fig. 6.

The hot-water apparatus has been fitted up by Messrs Perkins and Heath in various public buildings, warehouses, and gentlemen's houses; and, while sufficiently effective for the desired end, it has been proved to be attended with as few drawbacks as any regulated mode of heating whatever. But there is a great obstacle to its general adoption in its expensiveness. The temperature also becomes at times so high as to cause a disagreeable odour. Another objection is its liability to burst; though, from the tubes being of malleable iron, such an accident causes more inconvenience than serious danger.

Conservation of Warmth.

The art of warming embraces not only the production and distribution of heat, but the construction of apartments with a view to prevent its escape. The way to effect this—setting aside in the meantime the necessity of renewing the air—is, in the first place, to make the walls, floor, windows, doors, &c., as impervious to air as possible, to prevent the heat from being carried off by currents; and in the next place, to make them bad conductors of heat. For this last purpose, the walls ought to be sufficiently thick, and, if possible, built of non-conducting materials. Solid iron would make a cold wall; wood, a warm one; and in this respect brick or porous stone is preferable to hard stone. But the chief element in a warm wall is that it be *double*, which every wall in effect is, when it is lined by a coating of plaster, kept apart from the wall itself by the laths. The plate of confined air between the two is the most effectual barrier to the passage of the heat outwards that could be contrived. By making iron walls double or cellular, with a lining of plaster, they might be rendered as warm as wished. Windows are a great source of cold, not merely by admitting cold air, but by allowing the heat to pass by conduction through the thin glass. The air of the room that touches the window is robbed of its warmth, and is constantly descending in a cold stream towards the floor. There is thus a cold influence felt from a window, however close it is. This is partly arrested by window-blinds, shutters, and curtains, which check the flow of the air, and retard its carrying power. But a far more effectual plan is to have double windows: either two frames, or double panes in the same frame. The loss of heat by a double window is said to be only one-fourth of that by a single. Double windows are considered essential in countries where the winters are rigorous.

By carrying those principles far enough, we might succeed in well-nigh imprisoning the heat, and thus produce a house of ideal perfection, so far as mere temperature is concerned. But for the habitation of living beings, another condition, seemingly antagonistic to the former, is no less requisite—'air, as free as that on a mountain-top.' In general practice, the two hostile conditions are not so much sought to be reconciled, as compromised; and then, as usual, neither object is well attained. Circulation of air is got accidentally, through the imperfections of structure in our rooms—through the chinks and bad fittings of the windows, doors, floors, and the uneconomical fashion of our fireplaces. Were houses much better constructed than they are, the inmates would in many cases be suffocated outright, as they often partially are with the degree of perfection we have already attained. Neither the airing of our houses, nor the art of building them solid and warm, can advance to perfection, until the former be no longer left to chance, but be in every case secured by special apparatus capable of direct control. We now proceed to consider how this is sought to be attained; confining ourselves still to the leading principles, and only noticing a few of the specific plans that have been put in practice.

VENTILATION.

The importance of constantly respiring pure air is more fully considered in the paper on PRESERVATION OF HEALTH. For our present purpose, it will be sufficient to bear in mind the following facts. Fresh air is chiefly made up of two gases, which are everywhere found to be in the same proportion: nitrogen forming about four-fifths of its bulk, and oxygen forming one-fifth. It also contains a very variable quantity of vapour of water, and a smaller but pretty constant quantity of carbonic acid gas (see CHEMISTRY)—namely, 1 part in 2000 by measure. When a portion of this air has been once breathed, it is found to have undergone several changes, which render it unfit to be breathed again. The chief vitiation consists in a portion of the oxygen being abstracted, and nearly as much carbonic acid gas substituted for it, the carbonic acid having been formed by the oxygen uniting with the carbon of the blood. The average quantity of carbonic acid in expired air or breath is found to be 4·3 per cent. by measure. Now this gas, when taken into the lungs, is a poison, and tends to arrest the vital processes. Like other poisons, however, it can be rendered harmless by *dilution*. The small proportion naturally existing in the atmosphere is perfectly innocuous, and may be considerably increased without sensible effect. But it is decidedly prejudicial to breathe for a long time air containing 1 measure in 100 of carbonic acid, especially if the carbonic acid has been formed by breathing or combustion, at the expense of the oxygen of the same air; and it is considered desirable that the proportion should never exceed 1 in 500. We may assume, then, what is near the truth, that 20 cubic feet of air pass through the lungs of a man in an hour. To reduce the poison of this to 1 per cent., at which point it is barely respirable, it requires to mingle with as much fresh air as will make a mixture of nearly 100 cubic feet; and to make the dilution at all safe, it must be carried five times as far. In other words, the respiration of one human being vitiates hourly about 500 cubic feet of air.

In addition to carbonic acid, expired air contains an undue amount of watery vapour. Minute quantities of animal matters are also exhaled with the breath, which in close ill-ventilated apartments form a clammy deposit on the furniture and walls, and, by putrefying, become organic poisons.

A further necessity for the constant renewal of fresh air arises wherever lights are burnt. The deteriorated air of a fire goes off by the flue, but lights are generally burnt where the products must mingle with the atmosphere of the apartment. Now, a pound of oil in burning consumes the oxygen of thirteen feet of air, and produces a large amount of water in vapour, and also of carbonic acid. Every cubic foot of gas consumes the oxygen of ten feet of air, and forms at least one foot of carbonic acid, besides watery vapour, sometimes mixed with sulphurous fumes.

There is in so far a natural provision for preventing us from being poisoned by the products of our own respiration. The breath, being warmer, and thus lighter than the surrounding air, rises upward as it issues from the mouth, and thus saves us, without trouble or thought, from all risk of inhaling it a second time. But the process is perfect only in the open air: under a close roof, the vitiated air is arrested and accumulated, and is soon spread through the whole room.

In an ordinary apartment heated by a common open fire, there is an imperfect kind of ventilation always going on by means of the fire, which draws in through the door, windows, and other apertures, fresh air to supply that consumed by itself, or which the chimney-draught otherwise carries off. This is imperfect, in as far as the draught may only clear a certain space near the bottom of the room, between the door or windows and the fireplace, leaving the most foul and heated portions floating above the level of the chimney-breast; also, in as far as it only operates when there is a fire, and therefore not in the summer-time. It therefore becomes desirable that a regulated mode of ventilation, calculated to be thoroughly and at all times effectual, should be applied to ordinary apartments. It is not less necessary that churches, court-rooms, theatres, and all large halls in which great numbers of persons assemble, should be subjected to a mode of ventilation, regular, certain, and complete. Nor is it unworthy of notice that a regular means of ventilation is also required in stables, cow-houses, and other places where valuable animals are kept.

Ventilation consists of two operations—the removal of the foul air, and the introduction of fresh. Though neither operation can go on without the other going on at the same time, it is convenient to consider the two separately.

The agents employed in removing the air from apartments are chiefly two: that by which nature effects the ventilation of the earth on a grand scale (see METEOROLOGY)—namely, the draught of ascending currents produced by difference of temperature; and mechanical force, such as pumping. The former is the more common, and is the only one applicable to private houses.

The column of air in the chimney of a lighted fireplace being expanded and comparatively light, exerts less than the prevailing pressure on the air immediately under and about its base. On the principle, therefore, explained in HYDROSTATICS and PNEUMATICS, the air below and around it pushes it up, and flows in to take its place; the velocity of the movement being in proportion to the height of the chimney and the degree of heat. Thus, although it is often convenient to speak of the air being *drawn* or *sucked* into the chimney, the force does not lie in the chimney, but in the greater pressure of the air behind. If we were accustomed to look at the movement in this light, it would tend to do away with many of the confused and erroneous notions entertained on the subject of chimney-draught, and on ventilation generally.

Wherever, then, there is a heated chimney, there is a means of removing the foul air. And in rooms moderately lofty and spacious, with windows and other fittings not closer than usual, and a chimney-mouth of the usual width, there is little risk, when there are only a few inmates, of any serious vitiation of the air. The heated breath that ascends to the ceiling has time to diffuse itself gradually, and be drawn in a diluted state into the currents that are setting from all quarters towards the chimney. These currents, however, are one great objection to this mode of ventilation, as they consist in great part of cold air that has just entered by the doors and windows, and are strongest where the inmates sit to enjoy the fire.

The ascent of foul air to the top of the room dictates its exit in that direction, rather than low down at the mouth of the chimney. It is conceived by some that the carbonic acid of the breath, from its greater weight, must be chiefly at the bottom of the room; but this is a mistake. The heated breath ascends instantly, because it is, as a whole, lighter than the air around it; and the carbonic acid in it does not tend to separate from it and fall down by its superior weight, but, by the law of the diffusion of gases (see METEOROLOGY), seeks to spread itself equally all over the room, and would do so though it were lying at first on the floor. It is on the principle of the foul air ascending at first to the top of a room, that Dr Arnott's ventilating-valve is contrived. The valve may be used to supplement the open-fire draught in small and crowded apartments, and is essential where the fire is burned in a close stove or in the smokeless grate. The valve is represented at *v*, fig. 1. An aperture is cut in the wall over the chimney, as near to the ceiling of the apartment as may be convenient. In this is

suspended a valve, capable of opening inward to the chimney, but not in the other direction, by which means a return of smoke is prevented. The valve is so balanced on its centre of motion, that it settles in the closed position, but is easily opened. A flap of thirty-six square inches is sufficient, where there is good chimney-draught, for a full-sized room with company. This simple apparatus may be painted, or otherwise made ornamental. It operates by virtue of the draught in the chimney. Whenever that is active from the presence of a fire, the valve is seen to open inwards, and a stream of air from the top of the apartment passes through into the chimney, and is carried off. The operation is precisely equivalent to the stream of air always passing into a chimney between the fire and the mantel-piece, but has the great superiority of draining off the most impure air in the room. A wire descends to a screw or peg fixed in the wall, by which the opening of the valve may be limited or altogether prevented. This is a far more efficient plan of ventilation than an open window, or an opening in the wall near the roof, leading merely to the outer air; where there is an open fire in the room, such openings rather admit a rush of cold air than let out the foul.

There is generally more or less draught in a chimney even without a fire, from the air within being slightly warmer than that without; and this action might be strengthened by burning a jet of gas within the ventilating aperture at *v*. Where a house is to be built new, some recommend having special ventilating-flues in the walls, separate from, but close to the fire-flues, so that the air may be heated, and an ascending current produced. In weather when fires are not required, the draught can be maintained by gas-jets at the entrances to the vents. This plan of causing a draught by gas is applicable to churches and apartments without fireplaces.

Where a fire is burnt for the express purpose of producing a current of air, it is called ventilation by *fire-draught*. The plan has been exemplified with success in mines, where a fire being lighted at the bottom of a shaft, air is drawn off in all directions around, and sent up the shaft; to replace which, fresh air is constantly pouring down other shafts.

Mr Fleming of Glasgow applied the same principle with great success to the ventilation of a large pile of buildings in that city which was densely crowded with poor inhabitants; and in doing so, he availed himself of the chimney-stalk of an adjoining factory. From an upper corner of each of the apartments, he led a metal tube, of about an inch and a half in diameter, which, passing into the adjacent gallery, there met and joined a general pipe, nine inches in diameter, suspended immediately under the ceiling. One of these general pipes passed along each gallery in the four stories, and the whole joined in one vertical tube at the end of the house, communicating at the bottom with the base of the chimney-stalk. It follows that, when this flue is active—and practically it is so day and night—a draught is established upon the air-contents of every room in the house.

Many of our large buildings, as St George Hall in Liverpool, and the Millbank Penitentiary, London, are ventilated by fire-draught. Fig. 7 shews an arrangement by which a school or church may be ventilated: *aa*, the flooring perforated with holes, through which air, warmed by hot-water pipes, passes to the interior. The ceiling, *bb*, is perforated, leading to a chamber which communicates with a vertical flue, *cc*; which leads to the fire-place of the warming-apparatus, situated at the foot of a flue, *ed*. As the only air which reaches this must pass from *cc*, a constant current is maintained therein, and also through the apertures in the ceiling. Dr Reid has exemplified this method, first in his own class-room in Edinburgh, and afterwards in various public buildings.

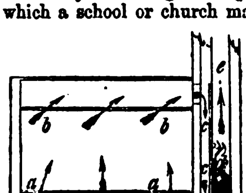


Fig. 7.

A description of his arrangements in the House of Commons involves the principles of heating, or rather of temperature—regulation, as much as those of ventilation. 'The air'—we quote the account given by Drs Ronalds and Richardson of this much-agitated affair—'is supplied from Old Palace Yard to the basement of the building, passing first through a fibrous veil 42 feet long by 18 feet 6 inches deep, for the exclusion of visible soot, it arrives at the heating-apparatus, consisting of large chambers intersected by steam-pipes, and proceeds from thence to other chambers, where it can be mixed with cold air, and brought to any required temperature. The floor of the house is double, and the space below the floor can be connected by means of valves with the hot-air chamber. The floor is perforated by a great number of apertures, and these are covered with hair-cloth, so that the hot air, in escaping from the floor into the body of the house, is infinitely divided, and no perceptible current is experienced. Having performed its functions, the vitiated air ascends to the ceiling, which is also double and perforated, in the same manner as the floor, whence it is carried off by the draught created by a powerful fire under a chimney-shaft erected in another part of the building.'

'The plan adopted by Sir Charles Barry for warming and ventilating the House of Peers, the royal ante-chamber, and the public lobby, differs from that just described both as respects the admission of the air and its removal. The floors of the rooms are impervious, and are heated in the first instance simply by the passage of hot air below them; the hot air then escapes by passages along the external sides of the rooms to the ceiling, which is divided into two compartments—the one for the admission of the warm air, entering at the sides, and the other for the exit of the vitiated air. The warm air, after passing below the floor to the roof, becomes somewhat cooled, so that its temperature on entering the ceiling is a few degrees lower than that actually present in the room; it consequently descends to the level, at which it is at once heated again; and deteriorated by combustion, respiration, &c., rises through the centre of the room, passing through the ceiling to a foul-air chamber above, whence it is conducted to a chimney, and carried off by the peculiar motive-power first suggested by Dr Richardson to the production of draught. This power consists of a jet of steam, which, when produced under a pressure of 32 pounds to the square inch, is capable of setting 217 times its bulk of air in motion; 10,000 cubic feet of air are thus gradually diffused through the three apartments per minute; no draught of any kind is perceptible; and no inconvenience is experienced from dust or other solid particles being carried mechanically forward by the air, as is said to be the case when the air enters from below.'

In other cases, as at the prison in Millbank, warm air is admitted at the ceiling, and carried off by the draught of a chimney in connection with the sides or lower part of the rooms.

In these last-mentioned instances, the apparatus provides as well for the admission as for the removal of air. In ordinary dwellings, no special provision is in general made as to admission. It is, in fact, not absolutely necessary; for the removal of a portion of the air of a room never fails to secure the entrance of a fresh supply somewhere. Whenever the chimney-draught or other means removes a little of the pressure inside the room, the pressure without forces air through every opening and chink; and even, were there no actual openings, would force it through the porous substance of the structure—such as mortar, and even wood

itself. But this irregular source of supply has various inconveniences. It often requires more force to strain the air in this manner than the draught is possessed of, and then the chimney smokes; it is smoke produced by this cause that is curable by opening the door or window. Another objection is, that impure air is often thus drawn into rooms from the lower parts of the building and from drains about the foundation. For these and other reasons, there ought, in all cases, to be a free and legitimate entrance provided for fresh air, so as to give a control over it; and this entrance should be independent of the windows. It is a much disputed point whereabout in a room the air should be made to enter—some advocating openings for it near the floor, others near the ceiling; and it must be confessed that neither method has yet been rendered unobjectionable. One essential thing is, to prevent the air from rushing in with a strong current, by passing it through minute holes spread over a large space. A tube, for instance, leads from the outer air to a channel behind the skirting, or behind the cornice, and the air is allowed to issue into the room through minute holes or through a long, narrow, and concealed opening covered with perforated zinc or wire-gauze. The passage or tube leading from outside the wall can be more or less closed by a valve regulated from the inside.

But the great difficulty lies in the coldness of the air directly introduced from the outside, whether by the doors and windows, or through channels in the walls; and all such plans of ventilation must be considered as imperfect make-shifts. There can be little doubt that our descendants will look upon them as little less barbarous than we now think the arrangements of the palace of Cedric the Saxon, and the ventilation of Rowena's boudoir, as described in *Ivanhoe.*

The fresh air ought in every case to be warmed before being admitted, or, at least, before being allowed to circulate in a sitting-room. In the smokeless grate (fig. 1), the air is led directly from the outer atmosphere into a channel (1, 2) underneath the hearth, and escaping below the fender and about the fire, is warmed before spreading through the apartment. With stoves and heated pipes, the air should enter about the heated surface; in stoves on the cockle principle, the fresh air, as it enters, is made to pass between the casings of the stove. With an open fire, a very feasible plan is to make the fresh-air channel pass behind the fireplace, and allow the warmed air to escape from concealed openings about the chimney-piece and jambs, or from behind the skirting. In Condy's Ventilating-grate, the fire-box is constructed of hollow pieces of fire-brick communicating with the external atmosphere and with the room.

For a house with fireplaces of the usual construction, perhaps the simplest and most effective expedient is to admit the fresh air into the entrance-hall, and there warm it by means of a low-temperature stove or by water-pipes; its passage into the several rooms can then be provided for by regular channels, behind the skirting or otherwise. In America, perforations are frequently made in certain parts of the doors, before which silk curtains are disposed, so as to temper the currents. It is almost unaccountable that in this country the plan of warming the lobby and staircase is so seldom resorted to. To say nothing of the comfort thus diffused through the whole house, and the benefit in point of health, especially to weakly constitutions, the economy of the arrangement is beyond dispute. In the sitting-rooms, not more than one-half the usual quantity of fuel requires to be burned in the open fires; and in the bedrooms, as a rule, fires are rendered altogether unnecessary in the coldest weather. It ought to be observed, that when air is admitted by a regular and free channel, comparatively little is strained in by the windows and other byways.

Ventilation by Fans and Pumps.—The fan-wheel has been for many years used in factories, to which it is particularly applicable, from the readiness with which it can be kept in motion by the engine. It is essentially the same as the barn-fanners; the air is drawn in at the centre of the wheel, and flies off at the circumference by centrifugal force. The fan is placed at the top of a flue, into which branches from all parts of the establishment proceed; and when it is set in motion, it draws off the air from every apartment communicating with it. Dr Arnott observed, that in the fan-wheel as well as in the air-pump or bellows invented by Dr Hales, a great deal of power was wasted by 'wire-drawing' the air—that is, making it squirt through small valves or other narrow openings. He has shewn how this may be obviated by the following form of a ventilating-pump (fig. 8): *efhg* is the outer cylinder; the piston consists of another cylinder, *abdc*, suspended within it like a gas-holder, and dipping into water, WW. The outer cylinder is closed at top and bottom, but has at *e*, *f*, *g*, *h*, curtain-valves of oiled silk resting against wire-gauze, those at *e* and *g* being suspended outside, at *f* and *h*, inside. As the cylinder-piston, A, descends, the curtains at *g* open, and allow the air to issue, while air is drawn in at *f*; when it begins to ascend, the former valves close, and air is now drawn in at *h*, and expelled at *e*. Thus air is continually entering at the side *fh*, and being expelled at the side *eg*. By connecting, then, the side *fh* with the outer air, and the side *eg* with a system of pipes leading to the apartments of a building, fresh air may be forced in, and the foul air blown out; or by reversing the connection, the foul air may be pumped out of the apartments, which of itself will draw in fresh air, as before explained. Very little power is required to move the piston up and down; in the York Hospital, where such a 'Gasometer Ventilating Pump' has been in highly successful operation for several years, the motive-power is derived, by a very ingenious contrivance, from the descent of the water used in the establishment from a high reservoir to the lower parts of the building; the descent of every pint sends 250 cubic feet of air into the hospital. 2000 feet a minute is the rate of supply.

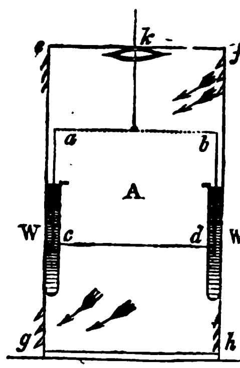


Fig. 8.

Transference of heat from the used air to the fresh.—We practise this kind of economy when in cold weather we breathe through the folds of a woollen handkerchief. The breath, raised to the temperature of the blood, leaves a great part of its heat in the handkerchief as it passes through; the cold inspired air absorbs this heat again, and enters the lungs considerably warmed. The same thing is more effectually done by the wire-gauze respirators invented by Jeffrey.

This is essentially the principle of the caloric-engine, or, more properly, hot-air engine, lately brought forward by Captain Ericsson of New York; but which is merely a copy of the invention of Dr Stirling of Perth, patented as early as 1816. The heated air, which has moved the piston, escapes through a body of thin metal slips or wires, which it heats; the fresh air as it enters re-absorbs the heat so deposited, and thus requires less heat from the furnace to bring it to the requisite temperature.

Whatever difficulties—or impossibilities, as some maintain—there may be in the way of turning this transferred heat into a fresh source of power, nothing seems simpler, in theory at least, than to economise heat in this manner

for the warming of dwellings and similar purposes. The idea originated with Dr Arnott, many years ago,

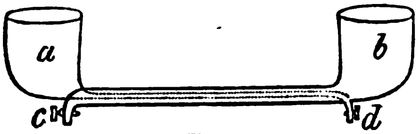


Fig. 9.

who thus illustrates it in the case of water: Suppose *a* a vessel of boiling water, with a thin metallic tube issuing from the bottom, and having a stop-cock at *d*; and *b* a similar vessel of water at freezing, the tube of which is larger, and envelops the other. When both are flowing simultaneously, the hot water, if the tube is long enough, will have lost all its excess of heat before getting to *d*, while the counter-current will have gained all that the other lost. In an experiment with tubes six feet long, the boiling water from *a* issued from *d* at 34°, and the freezing water from *b* issued from *c* at 210°. It is clear that if *a* were a bath, the warm water in it, after being used, might in flowing out be made to heat the cold water from a reservoir, *b*, flowing into another bath below *c*. We are not aware that the principle has ever been acted upon; but the possible economy of heat is obvious, and it only requires mechanical ingenuity to realise it.

It will at once strike the reader how desirable it would be to do the same with the impure heated air which we are obliged to eject from our dwellings. Where the ventilation depends upon the draught of a common chimney, it would seem impossible to bring the entering air in contact with that which is escaping; but where the mechanical force of a pump is employed, nothing seems simpler than to make the two currents run counter to one another for a certain distance in close contact through a system of tubes. The smoke even, which, with the most economical arrangements, still issues from the flues at a temperature considerably above that of the building, might be drawn into the current along with the foul air of the apartments, and the whole reduced nearly to the temperature of the atmosphere before being allowed to escape. Of course, there must be loss in the transference; but a large percentage would be saved, and the consumption of fuel would be reduced by that amount. Were this 'double-current ventilation' applied to churches, ball-rooms, theatres, &c., where thousands of persons are assembled, Dr Arnott believes that 'no other heating-apparatus will be required but the lungs of the company.' The plan seems available for private dwellings only where a number are arranged in one pile on the 'flat' system, as practised in Paris and Scotland, and as exemplified in Victoria Street, Westminster.

Even though such painstaking plans of economising heat might not pay at the present cost of fuel in this country, it is pleasing to think that there is such a resource in reserve. It is not with all countries as with us; and even our stores of coal are not inexhaustible. It is an unworthy, and, in the real sense of the word, an inhuman maxim, that bids us 'let posterity look to itself.' If the absorbing passion for present gain will not let us begin practising economy now, we may at least seek to devise and perfect plans to be in readiness when the necessity comes. It is not uncommon to hear the argument, that before the coals are done, something else will be discovered as a substitute. We are at a loss to imagine what the something is to be, unless it be the ingenuity to make the fuel that is now wasted in a year, last a hundred; and this we believe to be quite possible.

PREVENTION OF SMOKE.

The smoke arising from the furnaces employed at factories has been long felt as a great nuisance in most manufacturing towns, polluting, as it does, the pure air of heaven, and begriming every exposed object within the range of its influence. Those employing furnaces have also become generally aware that smoke is only a volatile form of fuel, and that if either less of it were generated, or if, when generated, it could be consumed, there would be a great saving in the expense of raising steam. These circumstances led to various devices for the combustion and prevention of smoke, and of late it has been rendered obligatory on the proprietors of all works to adopt means for that end.

The nature of smoke has been already explained. It is produced in greatest quantity when fresh fuel is added; more gas is produced than there is in general air to consume; and the coldness of the fresh coal makes its temperature too low to burn, though the air were abundant. When a sufficiency of air is admitted by opening the door of the furnace, the additional cold only still further lowers the temperature of the gases, and cools the boiler. The chief points aimed at in the various plans for overcoming this difficulty are—to introduce jets of air into the flame behind the furnace, so as to produce more perfect combustion, on the principle of the argand burner; to make the volatile matter of the fresh fuel pass over the hotter parts of the fire; and to add the fresh fuel in a gradual and regular way. We can notice only a few of the numerous contrivances that have been tried.

Mr Howard's invention, which is closely allied to that of Williams, is represented in the accompanying woodcut: *d* is the boiler surrounded by common flues; *a* is a coking-plate; *b*, the body of the furnace, with the ashpit beneath, which is closed against the admission of air; *e*, a fire-bridge, like that of a reverberatory furnace, and *c*, a space for the regulated admission of heated air. The coal is first coked on the coking-plate, and then pushed over on to the grate-bars, where there always exists a bright surface of burning coke. The gases generated in coking a fresh portion of coal pass over this heated surface before they come in contact with a fresh supply of warm air at *c*, and thus an almost perfect combustion of smoke is the result.

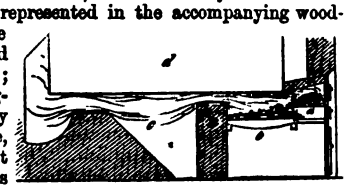


Fig. 10.

A somewhat similar plan is that of Stevens, which has been largely introduced, and has the favourable opinion of practical men; it is easily adopted, and not liable to get out of repair. The diagram, fig. 11, shews its application to a Cornish boiler, *aaaa*. *b* is the furnace-bar; *c*, the ashpit. There is a space between the end of the furnace-bar and the fire-bridge, *f*; below this space is another set of furnace-bars of smaller area, on which the red-hot cinders fall from the upper bars. The air passing along the ashpit, enters the furnace between two strata of fire, and thence between the caloric-plate, *d*, and bridge, *f*. The air is thus so intensely heated as to produce the entire combustion of the gases and prevent smoke.

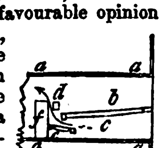


Fig. 11.

One plan in extensive use, and said to be successful, is that of 'alternate firing.' In this contrivance two fireplaces are used, both leading into a space called the mixing chamber. While one furnace is newly 'fired,' the other is in a state of high combustion, so that the gases pass from it into the chamber at an intense temperature, and there meeting with the smoke from the other furnace, raise it to combustion heat. There are numerous modifications of this principle of two fires fed alternately.

Of plans depending upon the slow and regular admission of the fresh fuel by means of machinery, it will be sufficient to notice that of Jukes. His grate-bars are

endless chains passing over rollers, and moved forward about an inch per minute. The coal employed is common siftings or screenings, which is heaped on the bars outside the furnace-door, which slides upwards. The door is left a little open, and by passing under it, the small coal is spread uniformly over the bars. The air is constantly supplied through the bars directly to the fuel while burning, and in this way perfect combustion is obtained. The bars, being slowly moved on, carry the ashes to the ashpit, which lies at the back of the grate. Jukes's apparatus was applied to the furnace of the engine which prints this work in 1848, and has been completely successful; it is rare that a single particle of smoke can be seen issuing from the chimney, and the saving in coal and attendance is decided.

Without any essential alteration on the common arrangements of a furnace, much may be done for the prevention of smoke by the expedient of having a double fire-door, with the inner plate pierced with numerous small holes. A self-regulating valve in the front plate admits more or less air, according to the state of the fire; and this air, heated between the plates, passes in small jets through the holes, and consumes the hot vapours. It is also found that a proper proportion of parts in the furnace, flues, &c., will of itself secure the absence of smoke.

LIGHTING.

Artificial lighting depends upon the fact, that solid bodies when heated to a certain degree, become luminous or *incandescent*. The luminosity begins at the temperature of about 800°; and as the heat is increased, the red passes into a white of greater and greater brilliancy.

Gaseous bodies, however hot, give little or no light. Air hot enough to make a body held in it red, is itself not luminous; and the flame of hydrogen gas, which, when burnt in oxygen, produces the greatest heat known, is barely visible. In order to produce light, then, we must have a highly heated solid substance. In practice, this is best obtained by burning volatile compounds of carbon and hydrogen. The combustion of the hydrogen produces intense heat, and the particles of solid carbon, before being themselves burnt, become white in the hot gas.

While pure carbon may be used as fuel for producing heat, carbon and hydrogen united, and burning in the shape of flame, produce most light, because the combustion is more rapid, and the heat more intense. Carbon and hydrogen combine in a variety of ways, and produce a numerous class of compounds, called *hydro-carbons*, some of which are solid, some liquid, and others gaseous, but mostly capable of being vaporised by heat. A number of natural products, such as the animal and vegetable oils, tallow, wax &c., are altogether composed of such compounds, and can be vaporised or distilled without leaving any solid residue. These form the readiest sources of light, because the substances may be distilled or vaporised by the heat of the flame that produces the light, as in the case of a candle. Coal, on the other hand, which is only partly vaporisable, must be distilled by the heat of a furnace, and this makes the distinction between gas-illumination and illumination by lamps or candles. In both cases, the source of light is the combustion of vaporised hydro-carbons.

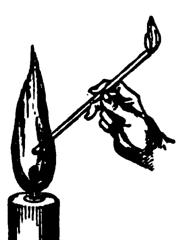


Fig. 12.

Structure of Flame.—The flame of a lamp or candle, or simple gas-jet, consists of a hollow cone, in the centre of which there is no combustion. The central space appears dark only by contrast with the luminous cone which surrounds it. It consists, in reality, of transparent invisible compounds of carbon and hydrogen, which are constantly rising in vapour from the wick. If a glass tube, open at both ends, be held obliquely in the flame of a candle, with its lower extremity in the dark central space above the wick, it will conduct away a portion of the combustible vapour, which may be kindled like a gas-jet at its upper end, as represented in fig. 12. This dark portion of the flame may be called *the area of no combustion.*

The luminous cone which envelops the dark space is *the area of partial combustion.* The oxygen of the atmosphere penetrates to this depth, but not in sufficient quantity to oxidise or burn both the carbon and the hydrogen; it therefore unites with the hydrogen, for which it has the stronger attraction, and leaves the carbon free. The outer cone is named *the area of complete combustion*, because there the carbon meets with sufficient oxygen to burn it entirely. The light is produced in the area of partial combustion, where the carbon is set free from the hydrogen in the form of solid particles, and is heated to whiteness by the combustion of the hydrogen. The combustion of the carbon in the outer cone, by which it is converted into carbonic acid gas, produces heat, but so little light as to be barely traceable.

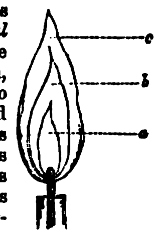


Fig. 13.

a, Area of no combustion.
b, Area of partial combustion.
c, Area of complete combustion.

That carbon exists in a solid state in the white part of a flame, is readily shewn by holding a piece of white earthenware into it, which becomes coated with carbon in the form of soot. No soot is deposited in the dark or no-combustion area of the flame, because there the carbon is in chemical combination with hydrogen, forming a gas. The carbon becomes solid only when the hydrogen deserts it, as it were, to unite with oxygen.

The highly illuminating power of compounds of hydrogen and carbon is thus traced to the fact, that *their hydrogen and carbon do not burn simultaneously, but successively, and in such a way that the one heats the other white hot.* It is quite possible to make them burn simultaneously; but when they do, the light evolved is very feeble. This is seen in the Bunsen burner alluded to, p. 470.

ILLUMINATION BY CANDLES AND LAMPS.

In principle, these two modes of lighting are the same. The essential parts of a lamp are a vessel containing liquid fat, from which a portion rises gradually by capillary attraction through the wick to the flame. In a candle, the solid fat below the flame is melted into the form of a hollow cup, which forms a reservoir for the liquefied portion, and becomes thus a tallow lamp. As the manufacture of candles is described in CHEMISTRY APPLIED TO THE ARTS, our remarks here may be confined to lamps.

The chief difficulties that attend the use of lamps as a source of light are—First, to procure the complete combustion of the oil, so as to keep the flame from smoking; and second, to prevent the level of the oil in the reservoir from sinking as the combustion goes on. The round cotton-wick used in the old simple form of lamp was always attended with smoke and smell. The oils and fats are exceedingly rich in carbon, containing 70–80 per cent. of that element, and only 10–12 of hydrogen. The round thick column, then, of oil-vapour rising from the wick of an old-fashioned lamp, presents too little extent of surface to the air; the oxygen of all the air that can get access is chiefly taken up in burning the hydrogen, and a large proportion of the carbon ascends in the burnt air as smoke. The most essential improvement in this respect is what is known as the Argand burner, from the name of its inventor. In

this the wick is in the form of a ring. The flame is thus a hollow cylinder, with a current of air ascending through the inside, so that the burning surface is doubled.

Another part of Argand's improvement consisted in placing a glass cylinder as a chimney over the flame, by which means the flame is steadied and a draught created.

Subsequent improvements have had for their object to deflect the currents of air from their parallel course, and make them strike against the flame. With this view, glass chimneys are often made to contract a little above the top of the flame. In what is called the Solar Lamp, the deflection takes place lower down, about half an inch above the top of the wick. The flame is there made to pass through an aperture in a metallic cap fitted on the top of the burner, as represented in figure 14. By this arrangement, the air is both made to

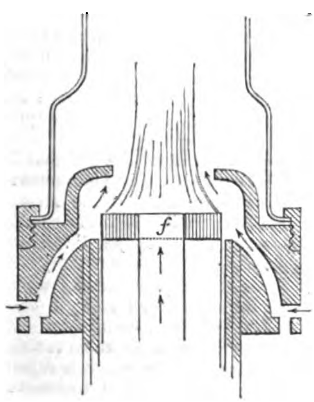


Fig. 14.

impinge against the outside of the flame, and the flame itself is forced inwards against the ascending column of air in its centre. The coarser oils can thus be burnt without smoke, and with great brilliancy of flame. Instead of the metallic cap, or flat metallic ring, glasses are now made of the shape represented in fig. 15, which serve the same purpose; they are, however, liable to break, if care is not taken.

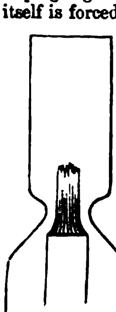


Fig. 15.

Another contrivance for making the air impinge against the flame, is to have a wire, *b* (fig. 16), ascending from the hollow space in the argand burner, and supporting a metal disc, or button, *a*, in the heart of the flame; this throws the ascending air in the inside against the flame, and makes it spread out like the cup of a flower. By combining these and similar contrivances, lamps are now constructed that burn rectified oil of turpentine (camphine) and other volatile oils, which otherwise burn with much smoke.

Fig. 16.

The second imperfection attending lamps, that, namely, arising from the change of level in the oil, is sought to be remedied by making the vessel wide and shallow; and in order that it may cast as little shadow as possible, it is disposed in the form of a wide ring round the burner. Other lamps are constructed on the principle of the bird-fountain, explained in PNEUMATICS. But the most effectual plan is to have the oil pumped up from the foot of the lamp to the wick by mechanical means. The most perfect mechanical lamp is that of Carcel, a Frenchman, in which the oil is pumped up by clockwork; it is, however, by far too expensive and difficult of repair, to be adapted for ordinary use. The French Moderator Lamp (fig. 17) is much simpler, and appears to overcome the difficulties of the case. The body of this lamp consists of a cylinder or barrel, B, the lower part of which contains the store of oil. On the top of the oil rests a piston, P, which is constantly pressed down by a spiral spring, situated between it and the top of the barrel. The piston is represented in the figure as resting on the bottom. Through the piston is inserted a small tube, which passes up to the burner at the top; and the pressure of the spring on the piston

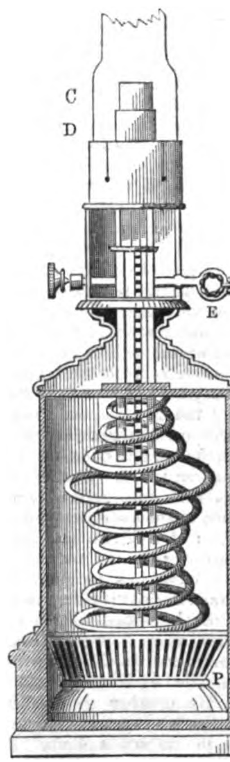


Fig. 17.

Fig. 18.

causes a constant stream of oil to rise up through this tube and feed the wick, C. What is not consumed, flows over the burner, D, and back into the barrel above the piston. It is above the piston also that fresh oil is introduced. When the piston has reached the bottom, it is wound up again by a rack and pinion, E; and a vacuum being thus formed, the oil above it is forced to the underside through a valve-kind of contrivance round its edge.

It is obvious that in this machine the flow of oil will be greatest when the piston has been newly wound up, and the spring is at its greatest tension. This inequality is regulated, or *moderated*—hence the name of the lamp —by an extremely ingenious contrivance. The tube through which the oil ascends (represented in fig. 18 on an enlarged scale), consists of two parts—a narrower, *b*, fixed to the piston, and rising with it, and a wider, *c*, fixed to the burner, and forming a sheath into which the other ascends. Within the upper tube is placed a

rod or wire, G, which descends so as to enter only a short way into the tube *b*, when the latter is drawn down to the full, as represented in the fig. Now, the effect of the rod within the narrow tube at *r* is to retard the passage of the oil; and it is evident that the effect will be greater the further the tube *b* is pushed up, because the narrow part is then made longer. The obstruction thus increases and diminishes with the force of the spring, and the flow of oil is rendered equable.

GAS ILLUMINATION.

The existence of an inflammable air, as a natural production, has been known from a period of great antiquity. It was observed to issue spontaneously from fissures in the earth; and has been employed in such situations, as a source of light and heat, both in ancient and modern times. This natural gas is also found in abundance in some coal-mines, where it constitutes the 'fire-damp' so destructive to the miner.

The artificial production of an inflammable air, by distilling coal in a close vessel, is first mentioned in a letter by Mr Clayton, rector of Crofton, Yorkshire, addressed to the Royal Society, May 12, 1688. Though well known to chemists from this time, it was only esteemed as a philosophical curiosity until the year 1792, when Mr Murdoch, an engineer, then residing at Redruth, in Cornwall, prepared coal-gas on a scale sufficiently large to light up his own house and office. In 1798, he was engaged to put up his apparatus at the manufactory of Messrs Boulton and Watt, Soho, near Birmingham, where he continued to experiment, with occasional interruptions, until the year 1802. It does not appear, however, that much attention was excited by these first efforts at gas-lighting, except among a very few scientific individuals, until the general illumination at the peace of Amiens afforded an opportunity for a more public display. On this occasion, the front of the manufactory was brilliantly lighted up by the new method, and it at once attracted the wonder and admiration of every one who saw it. 'All Birmingham poured forth to view the spectacle; and strangers carried to every part of the country an account of what they had seen. It was spread about everywhere by the newspapers; easy modes of making gas were described; and coal was distilled in tobacco-pipes at the fireside all over the kingdom.'

By the exertions of a Mr Winsor, a company was formed in 1804 for supplying London with gas; but it struggled for many years with the difficulties at once of inexperience and public prejudice. At length most of these difficulties were overcome, and gas-lighting, especially for streets and public buildings, began to spread over the kingdom. Its progress in dwelling-houses was at first retarded by the injurious effects of the impurities it contains in its crude state. But science has shewn how these may be effectually removed, and well-made gas is now free from all noxious properties. Until recently, the quality of the gas made in London was very inferior, and consequently it is not yet generally used there in private houses; but by employing a better kind of coal and other means, the quality has of late improved, and its use may be expected to extend. As it is, the capital of the numerous gas-works in London amounts to £3,000,000, and the daily consumption of coal exceeds 1000 tons.

The use of gas-lighting in cities and towns is now pretty general over the world. Where coal is scarce, it is prepared from resin, oil, refuse fats, soap-water, &c. Oil-gas was at one time extensively used in Great Britain, but though it is of very superior quality, the comparative economy of coal-gas made the manufacture be given up.

The gas prepared from coal is neither a simple nor a single gas; it is a very variable mixture, chiefly composed of two inflammable gases, commonly known by the terms, heavy carburetted hydrogen, or olefiant gas, and light carburetted hydrogen. Both these gases are compounded of hydrogen and charcoal in definite proportions. The first—namely, olefiant gas—is composed of 2 atoms of hydrogen with 2 atoms of charcoal; or by weight, 2 hydrogen to 12 charcoal. Its specific gravity is ·9722, common air being considered as unity, or 1·000. When pure, it has no taste, and scarcely any smell; it burns with a dense white light, combining with three times its bulk of oxygen.

The second—namely, light carburetted hydrogen—is composed of 2 atoms of hydrogen, combined with 1 atom of charcoal; or by weight, 2 hydrogen to 6 charcoal. Its specific gravity is ·5555. It is this gas which is met with in coal-mines. According to the experiments of Sir Humphry Davy, it forms explosive mixtures with air when the latter is mixed with it in any proportion between 5 and 14 times its bulk; it burns with a yellowish flame, combining with twice its bulk of oxygen.

Other gases enter into the composition of coal-gas, though in smaller proportions; thus hydrogen, carbonic oxide, and nitrogen, are uniformly present; it also contains certain other compounds of hydrogen and charcoal in a state of vapour. To these last, in which the proportion of charcoal is very high, both the smell and a considerable increase in the luminous property are attributed.

The relative proportions of the different ingredients in coal-gas are ever varying, being dependent upon the quality of the coal from which it is made, and to a considerable extent upon the methods employed in its preparation; and, as may be supposed, it must vary also in its specific gravity and luminous quality. When it is made in the best manner from good coal, the specific gravity is sometimes as high as ·750; in other circumstances, it is as low as ·400, or even lower. The former specific gravity indicates with tolerable certainty a large proportion of olefiant gas; the latter, a superabundance of light carburetted hydrogen and hydrogen. And as the amount of light evolved by combustion depends greatly upon the quantity of olefiant gas, which has a high specific gravity, the specific gravity of any specimen of coal-gas may be taken as a pretty correct indication of its actual illuminating value.

The presence of hydrogen and carbonic oxide deteriorates the gas by diluting it; but when once produced, they cannot be removed. Carbonic acid and sulphuretted hydrogen are impurities which the manufacturer ought to separate. It is to the presence of sulphuretted hydrogen that the tarnishing effect of bad gas upon paintings, silver plate, &c., is to be ascribed.

Manufacture of Gas.

The best coal for gas-making is that which is called *cannel*, or parrot. Of the cannels, the famous Boghead coal, or Torbanehill mineral, stands highest. A ton of this mineral yields 15,000 cubic feet of gas, of the specific gravity of ·752; while a ton of Newcastle coal yields 10–12,000 feet, specific gravity ·4–·500; and some other English coals, 8–10,000 feet, of specific gravity as low sometimes as ·320.

An average specimen of Newcastle coal, for example, consists of 82·12 per cent. of carbon, 5·31 of hydrogen, 1·35 nitrogen, 1·24 sulphur, 5·69 oxygen, 3·77 ash or earthy matter. When the coal is exposed to a high temperature, a certain proportion, varying from 70 per cent. in Boghead coal to as low as 20–30, is volatilised, while the rest remains as coke, composed chiefly of carbon and earthy matter. The volatilised ingredients enter into a new series of combinations, giving rise not only to coal-gas, but at the same time to a variety of other products—namely, water, tar, naphtha, carbonate and sulphate of ammonia, carbonic acid, and sulphuretted hydrogen. The essential parts of the apparatus, by which the coal is distilled and the last-named substances separated from the gas proper, are rudely sketched in the annexed cut.

A represents the retort, of which several are commonly in use at once. It is a cylindrical, elliptical, or D-shaped vessel of clay or cast iron, of 6–9 feet in length, and 12–20 inches internal diameter. It is built horizontally into a furnace, in such a way that the fire

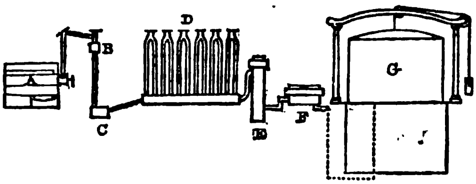


Fig. 19.

can act completely around it. The retort has two openings, both external to the building: one of them is the end of the cylinder, which is furnished with a closely fitting lid of iron; the other is an aperture in its upper surface for the exit-pipe, which passes from the retort to B, a vertical section of the hydraulic main, which is a round or square vessel of iron, passing above and in front of the whole line of retorts. It is half filled with liquid, into which the exit-pipe dips; it serves to collect the gas and other matters from any number of retorts, and to cut off its escape by any retort which may be open. It is connected by means of a wide pipe with C, the tar-cistern, in which the tar and everything deposited from the gas by cooling is collected. From the tar-vessel, a tube rises in a sloping direction to D, the condenser—a series of tubes through which the gas is made to pass, that it may be thoroughly cooled. To the condenser there is sometimes attached E, an upright cylindrical vessel filled with brushwood or dry coke, through which the gas passes before it is sent to F, the chemical purifier. There are usually several vessels of this kind, and of various forms: they contain quicklime, either dry or mixed with water to the consistence of cream. From the purifier, a tube passes to the bottom of the tank in which G, the gas-holder, or the gasometer, as it is improperly called, is suspended.

The retort being heated to a red heat, the charge of coal, about 200 pounds or upwards, is quickly shovelled in, and immediately gives off dense smoke and flames. The mouth of the retort is now closed by its lid, which extinguishes the flame by shutting off the air, and leaves no outlet for the dense vapours arising from the coal, except by the exit-pipe; they rush through this tube, and are heard bubbling up into the hydraulic main until the charge is exhausted.

It is of importance, in this part of the process, to attend to the temperature of the retort; for if it is too hot, some of the heavy gas will be decomposed, depositing part of its carbon, and forming light carburetted hydrogen; if, on the contrary, it is not of a certain temperature, there will be formed a large proportion of tar, and the gas will be light and of bad quality. It is also essential to draw the charge before it is quite exhausted, as the last portions of gas consist chiefly of hydrogen and carbonic oxide, both of which, as already stated, have a most injurious effect upon the quality of the whole product.

The dense vapours which pass from the retort into the hydraulic main consist of coal-gas mixed with tar, water, naphtha, salts of ammonia, carbonic acid, sulphuretted hydrogen, &c. Being subjected to a process of cooling in all parts of the apparatus as far as the brushwood box, the impurities are condensed, with the exception of the carbonic acid and sulphuretted hydrogen; and from the sloping or descending direction of the apparatus to the tar-cistern, they collect in it, and are pumped off as occasion requires. The gaseous matter still retains particles of tar mechanically mixed with it, from which it is freed by being forced through the *scrubber*, E. It is now made to enter the chemical purifiers, where it is either washed by agitation with a mixture of quicklime and water, or is passed through a succession of trays covered with thin layers of this substance in a slightly moistened state. In this process the lime combines with the sulphuretted hydrogen and carbonic acid, forming hydrosulphuret and carbonate of lime, which, being both solid, are retained; and the gas, now purified, is passed into the gasometer, where it is stored for nightly consumption.

Various improvements are every year being effected in the manufacture of gas—these modifications having reference chiefly to the retorts, the purifying apparatus, and the separation of the impurities, so as to render them available in some of the useful arts. Thus, clay and iron retorts of various shapes are now used; ammonia is separated by using alum, green vitriol, or dilute sulphuric acid, and is used as a valuable manure; gasometers are also variously constructed; the tar is economically employed as fuel or in the preparation of naphtha; and this naphtha is used either as a solvent, as an independent source of light, or in the impregnation of coal-gas, whereby its illuminating power is vastly increased.

Distribution of Gas.

The distribution of the gas from the gasometer to its places of consumption is effected in cast-iron pipes called *mains*, the size of which, in each case, it is the business of the engineer to determine. The pipes branching from the mains to supply gas to dwelling-houses or manufactories are called *service-pipes*, which, within doors, consist of small tin tubes.

Throughout all the ramifications of the fittings, the pipes have, or should have, an inclination to the main, and the main itself should incline towards the gas-work. The necessity for this arrangement arises from the presence of watery vapour in small quantity in the gas; being condensed into water in the pipes, it naturally collects in the lowest part, and at last interrupts the continuous flow of gas, so as to cause a flickering of the flame in the burners. Where the proper inclination of the pipes cannot be attained, this is obviated by placing a stop-cock and pipe at the part where liquid is apt to collect, so that it can be let off from time to time as it accumulates. An error in this respect in laying the service-pipes of a house, is a frequent source of domestic discomfort.

The quantity of gas charged for by gas-companies was at one time regulated by the number and kind of burners employed, and the time they were allowed to burn; but this was everywhere found to be a most uncertain and unsatisfactory method of guessing the consumption by any individual. It is now obviated by the use of a very simple and ingenious instrument invented by Mr Clegg, and subsequently improved by Mr Crossley; it is called the *gas-meter*, and consists of a hollow case of

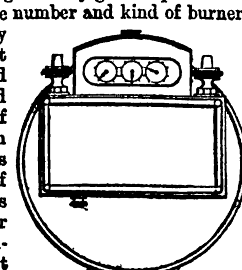


Fig. 20.

iron, containing an inner cylinder or drum, so constructed, that the gas passing through it, by the pressure it receives at the gas-work, causes it to revolve on an axis; each revolution allows a known quantity of gas to pass through the water, with which the outer vessel is partially filled, to the exit-pipe; and as the revolutions are registered by wheel-work and an index, the quantity of gas consumed is indicated with considerable accuracy. It is usually examined quarterly by a person employed by the gas-company, who charges the consumer according to the quantity indicated. The imperfections of this form of gas-meter are, that it is liable to have the water

frozen in severe weather, and that fraudulent consumers often tamper with the apparatus. To remedy this, various 'dry meters' have been contrived, but none have yet come into general use.

Regulators or Governors.—When other lights in the same premises have been put out, the gas that supplies these burners increases the pressure in the pipes, and is diffused over the other lights in the premises; and if not checked, there will be comparatively little reduction in the expenditure, although one-fifth of the lights are extinguished. To obviate these inconveniences, instruments called *governors* or *regulators* have been constructed, on the principle of making the pressure of the gas regulate the size of the opening through which it passes. The adjoining wood-cut represents a regulator invented by Messrs J. Milne and Son, which has been found to answer well in the premises where this sheet is printed. It can be readily placed upon any service-pipe, and being adjusted to the pressure required, it gives a regular flame and expenditure of gas, notwithstanding any variation of pressure in the main.

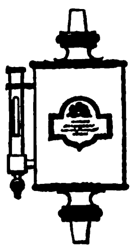
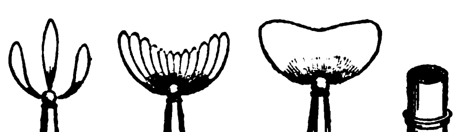


Fig. 21.

Burning of Gas.

From what has been said of the nature of flame, it will be readily understood that the manner in which gas is burnt may actually have an effect upon the amount of light derivable from a given quantity. It is found by experiment, that a properly constructed argand burner gives more light than can be obtained from the same quantity of gas by any other method of burning. In the argand, the flame is steadied and the current of air increased by the use of a glass chimney, which sensibly diminishes the size of the flame, at the same time increasing its brilliancy.

Other burners in common use are known by the names—single jet, cockspur, union-jet or fan, fish-tail, and bat-wing. In the single jet, the gas issues from a single aperture; in the cockspur (*a*), from three apertures, as shewn in the figure; in the union-jet (*b*), from a series of small holes, so that all the jets may unite laterally; in the bat-wing (*c*), from a slit instead of a



a *b* *c* *d*

Fig. 22.

series of holes; in the fish-tail, by making two jets cross each other, and yet issue from the same hole; and in the argand (*d*), from a circle of small holes, the centre of which is an open space for the admission of air. The relative quantity of light which they yield from the combustion of similar quantities of gas is thus given by Dr Fyfe: namely, single jet, 100; fish-tail, 140; bat-wing, 160; argand, 180. A high flame gives more light, with the same quantity of gas, than a low.

If the flame smokes in an argand, it is evident that some adjustment is necessary, and the gas should either be lowered or the chimney contracted, until it gives a clear cylindrical flame of three or four inches in height. In the fish-tail burner, if the flame flares, or makes a noise in burning, the gas should also be lowered; but to diminish either much below these points, does not effect a saving of gas in proportion to the diminution of light. Hence the important conclusion, that it is more economical when the light is too strong to procure a smaller kind of burner, or where several lights are used, to put out some of them altogether, than to lower the flame in the whole.

Bude Burner—Bude Light.—The Bude burner, so called from the name of the residence of its inventor, Mr Gurney, consists of two, three, or more concentric argand burners, each inner one rising a little above the outer. On the same principle, a powerful light is produced by a number of flat flames disposed in concentric circles like the petals of a rose. The *Bude Light*, also the invention of Mr Gurney, depends upon introducing oxygen into the centre of the flame, instead of air, as in the common argand. A light of the most dazzling brilliancy is thus produced. The House of Commons is lighted by this means, the brilliancy being softened by the intervention of a ceiling of ground-glass.

The *Lime-ball Light*, another of Mr Gurney's discoveries, though sometimes called the *Drummond Light*, is produced by directing the flame of a mixture of oxygen and hydrogen, against a piece of lime. The flame is itself pale, but the intense heat it communicates to the lime makes the latter give out a light rivalling that of the sun. The lime remains unaltered, shewing that a luminous body need not be combustible.

Comparative Cost of Gas-light.—Various calculations of the relative expense of gas-light, compared with other lights, have been made. Thus, when tallow-candles are 9d. per pound, wax-candles three times the price of tallow, train-oil 2s. per gallon, and coal-gas 9s. per 1000 cubic feet, it is computed that the relative expense will be as under—namely,

Wax, . .	100	Oil, . .	5
Tallow, . .	25	Coal-gas, . .	3

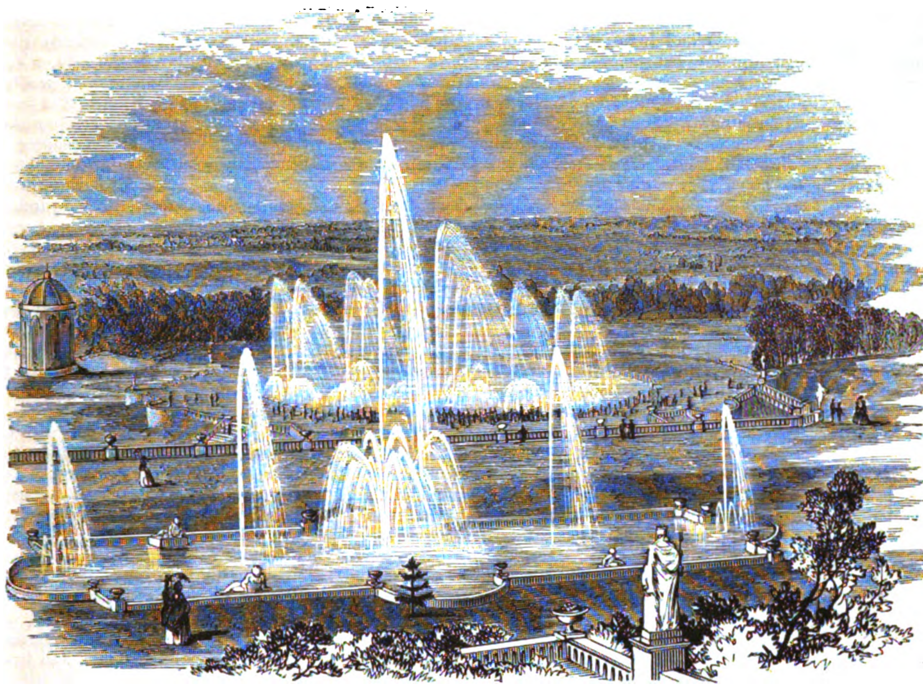
According to another calculation, 'when gas is at 4s. 6d. per 1000 feet, and dip-candles 7d. per pound, the cost of an equal amount of light from the two sources will be as 4s. 6d. to £1, 10s. 10d.'

Many individuals, who complain that the adoption of gas-light has proved no saving to them, will be surprised at the above statements. They will find, however, on examination, that they now light up their houses far more brilliantly than they were accustomed to do when candles or oil-lamps were in use, and that their equal expenditure is thus accounted for.

Naphthalised Gas.—When gas is passed through naphtha, it becomes saturated with naphtha vapour, which, being exceedingly rich in carbon, greatly increases the illuminating power of the gas. Apprehension of danger from the inflammability of the substance is perhaps the cause that this improvement is not generally adopted. It may be simply applied by making the gas, before reaching the burners, pass through a box containing a sponge saturated with naphtha.

Hydro-carbon Gas.—When steam is passed over red-hot coke, it is decomposed, its oxygen uniting with the carbon to form carbonic acid and carbonic oxide, and its hydrogen being set free. The mixture of gases thus generated, called water-gas, is inflammable, but scarcely at all luminous. It is therefore passed through a retort in which tar, resin, Boghead mineral, or other substance producing heavy hydro-carbons, is distilling, and thus receives the necessary amount of carbon. This new illuminating gas has numerous advocates, and is used in various localities; but it is still a question, whether the hydro-carbons necessary to mix with the water-gas, would not be an equally good source of light alone.

The employment of gas at a distance from towns, is limited by the expense of the apparatus as compared with the quantity of light required; but where the annual expenditure for light is not less than £40, it is probable that gas might be made with advantage. Gas made from oil or resin, owing to the comparative simplicity of the apparatus, is likely, on a very small scale, to be more economical than coal-gas.



SUPPLY OF WATER—BATHS—DRAINAGE.

AMONG the complicated arrangements of civilised life, few are of higher importance than those which relate to the command of water. Whether for dietetic and domestic purposes, for the bath, or for carrying away the corrupting refuse of our towns and cities, a liberal supply of good and wholesome water is an indispensable requisite. Admitting the necessity, we intend in the following pages to give some account of the water-supply, baths, sewers, and other sanitary provisions depending on this element, both in ancient and modern times—dwelling on what seems more especially applicable to the wants of our own populous localities.

SUPPLY OF WATER.

Water is one of the primary wants of human life, no less essential than air and food; it is, besides, peculiarly delightful to the senses generally, and a source of endless convenience; hence the strong and religious interest that has always been attached to the means of its supply. In the earliest records of civilisation, we read of the digging of wells, and of quarrels about the possession of them. The 'Pools of Solomon,' near Bethlehem, which remain now almost as perfect as when they were built, were connected with a scheme for supplying Jerusalem with water. In Assyria and Persia, from the earliest times, water has been conveyed to towns from astonishing distances in open channels or canals, and in subterranean tunnels or *kanats*. In Egypt also, and in China, gigantic works for conveying water, both for domestic use and for irrigation, have been in existence from remote antiquity. Nor were these undertakings confined to the eastern hemisphere; we have evidence of the existence of kindred works in pre-Christian America. The ancient city of Mexico, which was built on several islands near the shore of the lake, was connected with the mainland by four great causeways or dikes, the remains of which still exist. One of these supported the wooden aqueduct of Chapoltepec, which was constructed by Montezuma, and destroyed by the Spaniards when they besieged the city. Hydraulic works on a great scale had also been executed by the Incas of Peru.

AQUEDUCTS.

Of all the ancient nations, the Romans paid the greatest attention to the supply of water, and carried the construction of *aqueducts* to the greatest perfection and magnificence. In the original sense of the word (*aquæ ductus*, a duct or conductor of water), every leader or channel of water would be an aqueduct; but the term is used to signify specially a channel cut through mountains, and borne on arches across valleys, so as to convey water by a gradual descent all the way from its source to the place where it is wanted.

Rome at first depended upon water drawn from the Tiber and from wells; it was to Appius Claudius, about 312 years before the Christian era, that the Romans were indebted for the improvement of bringing superior water from a distance by means of aqueducts, and for several centuries after his time, additional works were constructed, as the necessities and luxuries of the city demanded. The *Aqua Appia* was only eleven miles long, but some of the subsequent ones were about sixty miles: that built by Claudius was forty-six miles, of which nine and a half were on arches; and it discharged 97,000,000 gallons in twenty-four hours. One of these aqueducts was formed of two channels, one above the other; the most elevated being supplied by the waters of the Tiverone (Anio Novus), and the lower one by the Claudian water. It is represented by Pliny as the most beautiful of all that had been built for the use of Rome. The Aqua Marcia, Aqua Julia, and Aqua Tepula, entered Rome by one and the same aqueduct, divided into three ranges or stories, each of which supported its own independent channel-way.

In general, the conduits, or water-courses, were built of stone, rough or hewn, occasionally of bricks, and in either case cemented by the finest tempered mortar. Some were of a square form, paved, and covered with flagstone or tiles; others were arched over, as shewn in the accompanying cut; and some were throughout of an elliptical form. This conduit, or stone-pipe (*c*), if we may apply such a term, was conveyed through hills by tunnels, and across valleys upon single arcades, or even upon double and triple tiers of arches. In general, these arches supported only one water-course; but occasionally each tier had its own conduit, so that an aqueduct presented a double or triple form. Having arrived at their destination, the waters were generally received in reservoirs, and conducted by leaden pipes, or by stone grooves, into private cisterns, or dispersed throughout the cities by means of public fountains, which were often adorned with all the magnificence and allegorical allusion of ancient architecture. These structures were under the charge of a public functionary; and it is from the treatise of Sextus Julius Frontinus, who was inspector of the aqueducts of Rome under the Emperor Nerva, that we derive most of our information respecting the water-works of the imperial city.

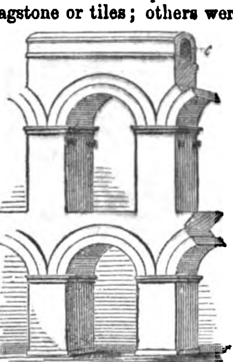


Fig. 1.

About 100 A. D. there were nine aqueducts, which, 'it has been calculated, furnished Rome with a supply of water equal to that carried down by a river thirty feet broad by six deep, and flowing at the rate of thirty inches a second.' (*Smith's Dictionary of Greek and Roman Antiquities.*) Another calculation makes the daily supply 300,000,000 gallons. The number of aqueducts was subsequently augmented to fourteen. Three of them are still serviceable, and modern Rome is more copiously supplied, perhaps, than any other city.

The system of aqueducts was also introduced into those countries that owed allegiance to the mistress of the world; in Greece, Italy, Spain, and Gaul, many were erected. That at Nimes was perhaps the oldest of these provincial aqueducts; it traversed a most diversified district, piercing hills and crossing valleys. At the place where it crosses the Gardon, it is termed the Pont du Gard; it is 300 yards in length, and is composed of three ranges of arches, one above the other, to the height of 160 feet.

Of the use of the aqueduct in recent times, two instances are alone worthy of notice—the *Lisbon* and the *Croton* at New York. The former, completed in 1738, is about three leagues in length; near the city, it is carried over a deep valley for a length of 2400 feet, by a number of bold arches, the largest of which has a height of 250 feet and a span of 115. The Croton Aqueduct, which conveys the waters of the Croton river for a distance of thirty-eight miles to the city of New York, is one of the greatest undertakings of modern times. It was commenced in 1837, and finished in 1842, and is calculated to discharge upwards of 60,000,000 gallons in twenty-four hours! The united supply of the ten London water-companies is stated at 81,000,000 gallons daily. The interior of the aqueduct is throughout of an arched or elliptical form, founded upon hydraulic concrete, built of square stones, and finally lined with brick prepared for the purpose. As the magnificence of aqueducts depends upon the height and number of arches requisite to carry them across valleys, it may give some idea of that under consideration, when it is stated that Haarlem River is crossed by fifteen arches, seven of which are of 50 feet span, and eight of 80 feet, the greatest height being 150 feet from the foundation to the top of the mason-work. No essential change occurs in the form of the channel-way from the fountain reservoir on the Croton, to the receiving reservoir on the island of New York—a distance of thirty-eight miles—except in crossing Haarlem River, to reach the island, and in passing a deep valley on the island, where iron pipes are used instead of masonry, to provide for the pressure consequent upon a depression from the regular plane. Thus the course of this artificial stream may be said to combine two principles—that of the ancient aqueduct, and a descent and ascent, as in ordinary pipes.

The water is first received in a reservoir covering thirty acres, and containing a month's supply; and from this it is conducted two miles further, to the distributing reservoir, which is 115 feet above the level of the tide. The whole cost of the work was about 9,000,000 dollars; and adding to this the cost of pipes, and arrangements for distributing the water in the city, it will make the total cost for supplying New York with water about 12,000,000 dollars.

Compared with the hydraulic works of the Romans, it must be confessed that the efforts made to supply modern cities, in Europe at least, are insignificant enough. It is only since the beginning of the sanitary movement, occasioned by the repeated visitations of cholera since 1832, that the subject of water-supply has at last occupied public attention. The result of every inquiry and every day's experience, has been to bring out more strongly the decided effects on the health of a community arising from the quantity and quality of the water at their command. Nor is the subject less important as regards refinement of taste and manners. Without abundance of water, there cannot be cleanliness; and the connection between physical and moral purity has been long felt and acknowledged. The chief points of interest on this subject may be arranged under the heads of the Sources of Supply, the Qualities of Water, and the Arrangements for its Distribution.

SOURCES OF WATER.

The great reservoirs of the globe are the oceans and seas. The water, however, as it there exists, is unfit for most purposes, on account of the large amount of other matters dissolved in it. The principal foreign ingredient is sea-salt, besides which it contains, in considerable amount, salts of lime and magnesia, along with iodine and bromine. But the process of evaporation or distillation constantly going on over the whole liquid surface of our planet, yields to the atmosphere a supply of pure water in the shape of vapour; and this descending in rain, forms the ultimate source of all *fresh* water, as opposed to the salt water of the ocean. It presents

itself chiefly in the forms of surface-water, rivers, and springs.

Surface-collection.—Rain-water, as it is formed in the upper regions of the atmosphere, is the purest that nature supplies; but in descending, it brings with it whatever impurities are floating near the surface, which, in the neighbourhood of towns, are numerous, consisting of various gases, together with soot and other floating particles, organic and inorganic. Rain-water has a strong affinity for organic impurities—that is, the corrupting ingredients derived from vegetable and animal bodies, and which are diffused over every surface in the vicinity of living beings; hence, when collected from the roofs of houses, it has a tendency to rapid putrefaction. Being free from saline ingredients, it is excellent for washing, but is not generally pleasant to drink.

But if we resort to a barren district of rock or sand, destitute of vegetation, and remote from the pollution of towns, we may obtain water such, that comparatively little organic impurity has entered into its composition. Notwithstanding several defects, it happens in various places that a surface-supply is the best that can be had, and is, on the whole, satisfactory.

Rivers.—The water obtained from running streams is in part what has flowed immediately from the surface, and in part the water of springs, shallow or deep. In any case, a considerable amount of contact with the ground has taken place, and in consequence saline matter is liable to be dissolved in a greater or less degree. The extent of the impregnation, as well as the kind of material dissolved, will depend on the rocks and strata of the river basin. Water flowing from granite rock, as the river Dee in Aberdeenshire, has a very small quantity of dissolved salts. Slate formations are also favourable to the purity of the water flowing over them. Sandstone is very inferior in this respect; while the limestone and chalk covering large districts of the country, impart a nearly constant amount of lime-salt to all the running streams. The lime is not unfrequently accompanied by magnesia.

River-waters, besides the qualities they derive from their primitive sources, are apt to contain mud and other matters in suspension, and are thus deficient in the clearness and transparency so essential to the satisfaction of the eye in a drinking water. The agitation which a running river undergoes prevents stagnation and such decay of organic matter, accompanied by an offensive smell, as occurs in canals; but it also deprives the water of some air and free carbonic acid, which renders it, according to the opinion of many, less fresh to the taste. Moreover, the water partakes of the extremes of summer and winter temperature, and in the hot months can hardly be free from organic impurities and insects. But, on the other hand, the supply from one of our large rivers is boundless and unfailing; and it conveys the surface-drainage and spring effusions of a large tract of country, without incurring any trouble or expense as to the original sources. With far more of mineral impurity than surface-water, river-water will usually present less of vegetable and animal impurity, in consequence of the tendency of the mineral impurity to increase, while the organic impurities diminish, by time and exposure.

Springs.—When water falling on the surface of the ground sinks into the soil, descending downward by slow percolation till it encounters an impervious bottom, and rises up at some convenient opening by the force of hydrostatic pressure, the outgush is called a spring. The conditions necessary to the occurrence of springs are —1*st*, The rain falling on the higher grounds must find admission into the interior to some considerable depth; 2*d*, By the force of the pressure from above, it must pass in lateral directions—in other words, it must find pervious beds or openings right and left; 3*d*, It must become hemmed in above by some stratum that does not give an easy passage, and therefore concentrates the pressure on the places where openings occur; and 4*th*, In the lower grounds where it has descended beneath an obstructing bed, there must be interruptions, fissures, or pervious strata, whereby it can rise to the surface again. Mountain districts, and a varied and irregular stratification of alternating pervious and impervious layers, are favourable to the concentration of water and its discharge in the form of springs; while, on the other hand, flat regions and uniform coverings of sand and gravel render springs impossible.

The slow percolation through the interstices of a gravelly layer, or the crevices of rocks, is the cause of the mineral impurities which distinguish the water of springs. At the same time, this slow action most effectually rids the water of any organic impurities contracted at the surface. Air, too, is largely taken in by compression along with the saline matter of the rocks, and the temperature of the interior is imparted to the whole mass; whence it happens that springs of moderate depth represent the average temperature of a climate. Very deep springs are of a higher temperature. The qualities that recommend water to the eye and to the palate belong in a pre-eminent degree to spring-water: it is clear, sparkling, and cool, and is totally free from the offensive taint so common in all other waters, as well as devoid of the animalcules generated by organic impurity.

QUALITY OF WATER.

Perfectly pure water is hardly to be found; rain-water, and even artificially distilled water, are only approximates. The impurities of water exist in one of two ways—either floating suspended in the form of solid particles, or in a state of solution. In the one case, there is a mechanical mixture; in the other, a sort of chemical union. The chief impurities may be considered under the heads of Mineral Matter in Suspension, Mineral Matter in Solution, and Organic Matter.

Mineral Matter in Suspension.—When running water comes upon a loose bottom, it carries the finer particles of sand and earth along with it, and the quicker its flow, the larger the pieces that it can keep afloat. If the water comes into a position of perfect stillness, the matters thus floated gradually sink to the bottom again —the heaviest first, and the others in succession. The particles gathered from beds of clay are the most difficult to separate from water by mere subsidence; either they are in a state of greater fineness than particles of lime, silica, or other minerals, or else the water has a more than ordinary adhesiveness to the material of clay. Whatever be the reason, the agitation of water in contact with a clay surface imparts a drab or rhubarb colour, arising from the diffusion of fine solid particles; and matter of such consistence is, for all practical purposes, incapable of being satisfactorily separated either by subsidence or filtration. Besides earthy matter, compounds of iron and lead are also in some circumstances present in a solid state, and may be got rid of by filtering.

To separate clay-powder from water, the practice has long been resorted to in India and China of putting in a piece of alum, which seems to act by the property it has of curdling some organic substances, and of causing others to adhere as dyes to such solid matters as may happen to be in the water. This is the oldest known device for purifying water by anything approaching to a chemical process.

Dissolved Mineral Matter.—Spring-water, which is generally clear and sparkling, holding no solid matter in suspension, is seldom without a large amount of dissolved mineral matter, sometimes as much as 2 parts in 1000, commonly from 1 in 1000 to 1 in 20,000. River and surface water also contains more or less dissolved minerals.

The great bulk of the solid matter held in solution in ordinary waters consists of salts; that is, combinations of acids with various bases (see CHEMISTRY). The saline bases are chiefly soda, potash, lime, and magnesia. The most material are the salts of lime and magnesia, as

they are the causes of what is called 'hardness' in water, which we shall speak of more particularly afterwards. The most important salt of lime is the *bicarbonate*, which is derived from chalk or limestone. Chalk or limestone is a *carbonate* of lime—that is, a compound of lime with one equivalent of carbonic acid—and is almost insoluble in water; but when water containing an excess of carbonic acid—as is the case with spring-water especially—passes over limestone, it gives it a double dose of carbonic acid, and converts it into bicarbonate, which is soluble. The waters having bicarbonate of lime for their chief impurity, are familiarly spoken of as the chalk-waters.

The other salt of lime often present in water, is the *sulphate* or *gypsum*. The important distinction between the bicarbonate and the sulphate lies in the fact, that the first, the bicarbonate, may be in great part precipitated, or thrown down in a solid form, by boiling; whereas the second, the sulphate, cannot be so precipitated.

Apart from its hardness, it has been made a question whether water containing salts of lime is injurious or not to the human constitution. The defenders of the hard water at present supplied to the metropolis even go the length of maintaining that salts of lime are necessary in the drink of animals, in order to supply the lime of the bones, and that it would be prejudicial to remove it. But the lime present in the bones of animals is found in abundance in their ordinary food; and the best answer to the argument is, that the inhabitants of many large cities—such as Aberdeen and Manchester—habitually drink water almost entirely destitute of lime, and yet shew no appearance of deficiency of bone. Dr Lankester holds that there is evidence to prove that carbonate of lime in large quantity is positively injurious; and most physiologists are agreed that pure water is the best for securing the health of animals and man. The lower animals give a marked preference to soft water, and thrive better on it; the horse will leave the clear spring, and go to the muddy pond.

With regard to magnesia, its salts are well known to act as powerful medicines when taken in large doses, and it may be presumed are not altogether without effect in the small quantities existing in ordinary magnesian waters. A foreign physician has lately made the observation, that magnesia is the characteristic ingredient of waters in the districts where the diseases called *cretinism* and *goitre* abound.

Of salts of *soda* and *potash*, the principal is common salt, or the muriate of soda. Sulphate of soda (Glauber's salt) occurs along with the muriate in the salt-springs of watering-places as well as in the sea-waters. None of all these salts have any effect on the hardness. In the case of sea-water, which is very hard, the effect is not due to common salt, but to the lime and magnesian salts dissolved in it; were it not for these, sea-water would be perfectly suitable for washing, although not for drinking. The Artesian-well water of London contains a large amount of alkaline salts, chiefly of soda; in one case, as much as 42 grains a gallon. Such water is extremely soft for washing purposes, and well adapted for cookery; but it is doubtful if so great an amount of alkali habitually imbibed be not injurious to the bodily system.

Salts of *iron* in considerable quantity make what are technically named *chalybeate* waters, which belong to the medicinal class. When the iron exists in the spring as carbonate, which is the most usual case, on exposure to the air, it is changed into the peroxide, and falls down in the form of an ochery precipitate. Salts of iron give an inky taste to the water, and a yellowish tint to linen washed in it.

Hardness in Water.

The quality of hardness in water is commonly recognised by the difficulty experienced in washing, and by the amount of soap necessary to form a lather. This quality is injurious also in the preparation of food; but its action is most universally felt in washing operations. It occasions an enormous waste of soap, an extra labour, and a corresponding tear and wear of clothes. The hardening matter contained in 100 gallons of spring-water, drawn from wells or borings in the chalk-strata, will destroy thirty-five ounces of soap—that is, the first thirty-five ounces of soap added to this quantity of the water will disappear without forming any lather, or having any cleansing effect. Soap is a compound, formed of an alkali (soda or potash) joined to an oily acid. (See CHEMISTRY APPLIED TO THE ARTS.) When a salt of lime, then, is present in the water, the lime decomposes the soap, and combines with the oily acid to form a lime-soap, which is insoluble, and has no detergent properties.

The most usual hardening ingredients are the salts of lime. Every lime-salt whatsoever hardens water and destroys soap in proportion to the lime present. Salts of magnesia are hardening salts, but not in a regular proportion to the quantity, there being some irregularities in their action. When a magnesia-salt is present along with a lime-salt, the magnesia acts rather as a curdler of the soap than as a destroyer. Salts of iron also produce hardness. Salts of soda and potash have no hardening effect.

Dr Clark, Professor of Chemistry in Marischal College, Aberdeen, has devised a scale of hardness which is now universally employed in the chemical description of waters. The hardening effect that would be produced by one grain of chalk dissolved in a gallon of water is one degree of hardness; in like manner, four grains per gallon would produce four degrees of hardness; ten grains, ten degrees; and so on. The degrees are expressed in numbers—thus, 1°, 4°, 10°, 15°, are one, four, ten, fifteen degrees respectively.

The scale of hardness increases with the consumption of soap requisite to form a lather. Professor Clark has made use of this fact in his process of testing for hardness—a process of extreme delicacy. It consists in the employment of a solution of soap of measured strength; and according to the quantity of solution requisite to form a lather of a certain duration, is the hardness of the water. By this test the value of a water for washing, and for all other purposes where hardening matter is an objection, can be determined with great ease, and with a precision scarcely equalled by any process in chemistry. The employment of the definite scale of hardness, and of the soap-test for measuring its amount, has tended more than any other circumstance to facilitate the determination of proper waters for the supply of towns.

Next to washing, the deleterious consequences of hardness are felt in various culinary operations, and especially in the infusion of tea. It is a fact of universal experience that hard water is unfit for tea. In experimenting with a series of waters at 4°, 8°, 12°, 16° of hardness, Professor Clark found that the difference of strength of the infusions, as manifested by the depth of colour, was evident at once to the eye, the softest water giving the greatest depth of colour. As the hardness of the water increased, the infusion was less transparent too, as well as weaker; and above 16°, it was disgustingly muddy. 'The only way,' he states, 'of making an infusion of tea with waters at 8°, 12°, or 16°, equally strong with an infusion by water at 4°, is to increase in each case materially the quantity of tea infused. Sub-carbonate of soda in crystals may be made use of in very small quantities in order to soften the water, and make it fitter for the purpose of infusing tea; it produces this effect by decomposing the earthy salts present; but if made use of in any proportion beyond what will exactly decompose the earthy salts present, the excess may indeed deepen the colour of the infusion—by dissolving some coloured vegetable extract, such as pure water would not dissolve—but it

will infallibly injure the fine flavour of the tea to all persons not accustomed to the taste of soda in their tea.'

According to M. Soyer—who was requested by the General Board of Health to try the effects of hard and soft water in cooking, and was provided with solutions of known hardness for that purpose—the operation of hard water is prejudicial both to meat and vegetables.

From the experiments on tea, already referred to, it would appear that when water approaches to 8° of hardness, it begins to be decidedly unfavourable to the infusion. It may be stated generally, that for the purposes of washing and cooking, a water of less than 6° is soft, but above this point the hardness becomes objectionable. At 8°, the water is moderately hard; at 12°, it is very hard; at 16°, the hardness is excessive; and much above this, it is intolerable.

To make these observations more intelligible, we may mention a few instances of known waters, with their place in the scale. In Keswick, the water of the new water-works there constructing is under half a degree of hardness; in Lancaster, it is 1½°; and in Manchester, 2°. The water of the Dee at Aberdeen, which is used for the supply of the town, is 1¼° of hardness. The river Clyde, supplying Glasgow, is 4½°, and may also be reckoned a soft water. The Thames at London, as well as the New River, is about 13°, while many of the tributaries of the Thames rise as high as 16°; but being all chalk-waters, they may be materially softened by boiling. Springs from the chalk commonly range from 16° to 18°; but particular springs are to be met with in some parts of the world four or five times as hard, from the presence of bicarbonate of lime. The water of the Treasury pump in London has from 50° to 60° of hardness. In many parts of the continent, hard waters abound; but the testing of waters has not been so much attended to there as in this country.

From an extensive examination of the waters of England and Wales, made by the General Board of Health, it appears that in England the hardness of springs in general is excessive (average 25°·86); that a very large number of rivers have an injurious and exceptionable amount of hardness (13°·05); and that surface-waters may be collected in a state that is to be considered soft (4°·94).

Lead in Water.

Injurious effects have frequently arisen from the contamination of water with lead, derived from leaden pipes and cisterns. Some kinds of water are known to act powerfully on a leaden surface, and others scarcely at all; but the qualities and circumstances on which the action depends have never been satisfactorily determined. Distilled water, and soft waters in general, act most decidedly, but by no means in proportion to their softness. It has been very generally held that the presence of free carbonic acid was the cause; but according to some recent experiments made by Dr Clark, distilled water, from which carbonic acid is carefully excluded, has still a very marked action on sheet-lead. The presence of air in the water seems one essential condition; light also increases the action. The saline matter present in hard water has been believed to hinder its impregnation by lead; but this opinion is set aside by the fact, that chalk spring-water, after softening by Clark's process, has no action on lead.

The presence of vegetable matter would seem to have more to do with it. Dr Clark finds that by adding a little vegetable matter—as a bit of raw potato—to the softened water, the action becomes decided; and it has been observed that when leaves drop by chance into a lead cistern, the spots where they lie become visibly corroded. On the other hand, it has been found that water coloured by peaty matter has less action than when clear, probably because water so impregnated usually contains very little air.

The water of Loch Katrine, from which Glasgow is to be supplied by the Corporation Water-works, now constructing, is of remarkable purity, having only two grains of solid matter of all kinds in the gallon, and about one degree of hardness. According to extensive sets of experiments by distinguished chemists, this water is allowed to have an intense action* on lead under certain circumstances—namely, '1*st*, If the lead be bright and highly polished; and 2*d*, If the lead and water be freely exposed to the access of air.' But it 'does not exert any noxious action on lead when the metal is in its ordinarily dull state.' The experience of Inverness and Whitehaven, both supplied with lake-water of equal purity, and of powerful action on bright lead, is said to bear out this result. A coating is held to be formed on the surface of the metal, which protects it from further chemical action. Still there are opposing facts to shew that this protective action is not always to be relied on; and that water that has passed through any considerable length of lead pipe, or stood for some time in a short one, or in a cistern, should never be used without care; a ninth part of a grain of lead per gallon has been known to derange the health of a whole community.

A remarkably soft water, obtained from Bagshot Heath, near Windsor, was found to have poisoned some of the Queen's hounds, and brought on painters' colic on one of the huntsmen. On this water Dr Clark has made the following statement to the General Board of Health: 'Through the kindness of Sir James Clark, I obtained a specimen of this water, and in a few days came to the unexpected result that filtration would separate the lead. Thus, a very simple practical means for separating lead, wherever it contaminates water, was discovered. This was in the summer of 1843; but the process first came into practical use in spring 1844. At a marine villa of Lord Aberdeen's, some of the servants suffered in health from lead in water derived from pipes. Sand-filters were put up under my direction at this villa, and subsequently at Haddo House. On making inquiry recently at his lordship's agent in Aberdeen, I learn that the filters have been in use ever since, and that the waters have been tested from time to time, without any lead having been discovered in them.' The experiment has been recently tried on a large scale at Sydney, and with success.

Organic Impurities.

The contamination of water by vegetable and animal substances in a state of putrid decomposition, and by the minute forms of life bred among such impurities, takes place in various ways. The most obvious and abundant source of this class of ingredients is the sewage and refuse of towns, and next in order may be ranked the contact with soils rich in organic matter. Among organic impurities may be classed offensive gases, such as carburetted, sulphuretted, and phosphuretted hydrogen; vegetable fibres in a state of rottenness; putrefying products of the vegetable or animal kingdoms; starch, muscular fibre, &c.; urea and ammoniacal products; vegetable forms—algæ, confervæ, fungi, &c.; animalcules—infusoria, entomostraceæ, annelidæ or worms, &c.

Water falling on a growing soil, and running off the surface to lie in stagnant ponds, is in very favourable circumstances for being tainted with vegetable and animal life. Water-plants will spring up and feed numerous tribes of animalcules, and each pool will be a constant scene of vitality. In such a state the water is usually unfit for drinking; the palate instantly discerns a disagreeable taint, and no one will use it who can do better.

The surface-water of a district overgrown with peat-

* The water of Loch Katrine is remarkably well aërated, having 7¼ cubic inches of air per gallon, of which 2¼ inches are oxygen. Dr Clark has a suspicion that the oxygen may turn out to be in some different state or modification from common oxygen.

moss has usually a peaty flavour, as well as a dark and dirty colour. The infusion of peat does not breed animalcules, being a strong antiseptic; but it is an objectionable ingredient nevertheless. Very slow filtration has been found to remove the colour of the infusion; but if the filtered water be exposed to boiling or evaporation, the colour returns, shewing that the peaty matter has not been altogether got rid of. Lime removes the peat most effectually, but there is both expense and risk in applying it. It is perhaps doubtful whether any specific unwholesomeness can be justly attributed to peat-water; but it is unpalatable, and the use of it is shunned by the inhabitants of peaty districts, especially in the hot months of the year, and even by cattle. The presence of peat in the lands used as collecting-grounds for surface-water—and it is generally such worthless tracts that are so employed—is a disadvantage attending that mode of supply.

Chalk-water, which, as it issues from a spring, is perfectly free from organic matter, has a source of contamination within itself. When exposed to light and air, the duplicate dose of carbonic acid that keeps the chalk dissolved, becomes decomposed; and the carbon of the decomposed acid gives rise to a green vegetation which soon acquires an offensive marshy smell. This subject will be further noticed when we come to speak of Clark's process for purifying chalk-water.

Organic matter in a putrefying state forms the worst kind of contamination that water can have. Though we may not know the precise effects of these impurities on the animal system, the single fact of their rendering the water repulsive to the taste, and nauseous to the stomach, would be sufficient to condemn their use. What is disagreeable to the senses, must be presumed to be unwholesome in addition, until the contrary is proved. Though no one has ever yet gone the length of maintaining, as a general truth, the wholesomeness of water abounding in vegetation, insects, and decaying matter, yet the water of the Thames, even within the influence of the tides, where it is contaminated by the whole sewage of the metropolis, found defenders until lately, on the plea that the amount of impurity was too small to do harm. This ground is at length given up; but Thames water above Teddington Lock is still sanctioned as safe water for the companies to supply to the inhabitants of London, notwithstanding the sewage of the numerous populous towns that the river receives above that point. As to this plea of smallness of amount, the highest medical authorities hold that it is impossible to say how small a quantity of organic matter in a state of fermentation may not do harm. The powerful effects of vaccination are produced by an almost imponderable quantity of organic vaccine matter. A very minute portion of organic matter present in water containing sulphates, is sufficient to decompose these sulphates, and render the water offensive, from the discharge of sulphuretted hydrogen gas.

We are not, however, left merely to presume that organic impurity in water is prejudicial to health. At a meeting of the Society of Arts, London, 1856, when the whole subject of water-supply was discussed, the chairman adduced the following striking facts: 'He would quote to them the results of a gigantic experiment which had been undesignedly conducted on half a million of human beings, and which would set this fact in a strong light. It happened that, in the last epidemic of cholera, a certain half million of population, dwelling contiguously over one large area, were drinking different waters; some from private wells, but the larger number—about four-fifths of the whole—from two commercial supplies. There were the mains of two rival water-companies going through the district, often literally side by side; one company supplying nearly 25,000 houses, the other nearly 40,000; so that in this vast experiment there were immense masses of population living, as far as could be judged, in all respects alike, except as to the one difference of their water-supply only. And that difference was, that one company drew its water from high up the Thames, where it was of comparative excellence, while the other drew its water from low down the river, where it was profusely contaminated with town-drainage. Among the population to which he alluded, there were in 1853-4 more than 4000 deaths from cholera; and when the epidemic had subsided, an inquiry was made, house by house, as to those deaths, and as to the water-supply of the several houses where they had occurred. The inquiry was conducted with every precaution, to avoid sources of fallacy; and the result was this: In the one set of houses, the mortality per 10,000 of the population was 37; in the other set of houses it was 130—that is to say, the cholera death-rate was 3½ times as great in the one set as in the other. It also fortunately happened in this very decisive case, that further information could be procured, so as to present almost a duplicate experiment. The returns of the Registrar-general had made it possible to ascertain the mortality during the preceding epidemic of cholera—that of 1848-9. Going back to that period, it was found that the mortality from cholera was about equal in the two groups of houses. The mortality per 10,000 of population was in the one case 125, and in the other 118. The tenantry which in the epidemic of 1853-4 suffered a cholera death-rate of only 37, had in 1848-9 suffered a death-rate of 125; and why? At that time, instead of drawing a comparatively pure supply from high up the river, it was drawing from nearly the same source as that other company which, on the late occasion, contrasted so unfavourably with it. Now, these unintended experiments had been on so large a scale that they might be considered conclusive; and as the difference between the two waters in question was only that one of them contained a large admixture of town-drainage, they might be considered to establish the extremely dangerous tendency of this contamination during periods of epidemic cholera. Among the population supplied with foul water, the death-rate was three or three-and-a-half times greater than among those who had the advantage of a more wholesome supply.'

Living Products of Organic Impurity.

We have already made repeated allusions to the occurrence of living vegetation and animals in water, of which some forms are visible to the naked eye, while innumerable others are disclosed by the microscope. These products in the London waters have been carefully studied by Dr Arthur Hassall, who has given valuable information respecting them, bearing on the practical arrangements for maintaining the purity of a town supply.

Dr Hassall states that the deeper wells, and spring-water in general, contain little or no living organic matter. Consequently, it is quite possible to obtain a liquid perfectly free from animalcules and vegetation; and *it is not true that every drop of water teems with life.* The presence of living creatures, vegetable or animal, discernible either by the naked eye or by the microscope, is a proof of organic taint in the water, and is one of the tests of this kind of impurity.

With respect to rain-water, Dr Hassall states, in his evidence before the General Board of Health: 'I have made several examinations of rain-water immediately after its descent to the earth, obtained in both town and country, and can confidently assert that it does not, in general, contain any form of living vegetable or animal matter.'

The conditions necessary for the development of vegetation and animalcules, over and above the presence of matter for them to feed on, are *air*, *light*, and *stillness*.

With regard to the probable effects on health of living creatures contained in water, Dr Hassall's observations are worthy of attention: 'All living matter contained

in water used for drink, since it is in no way necessary to it, and is not present in the purest waters, is to be regarded as so much contamination and impurity—is therefore more or less injurious, and is consequently to be avoided. There is yet another view to be taken of the presence of these creatures in water—namely, that where not injurious themselves, they are yet to be regarded as tests of the impurity of the water in which they are found.'

The grosser kinds of organic matter held in suspension in water are visible to the naked eye; the minuter are revealed by the microscope. A ready way of ascertaining the presence of such impurities, is to fill a stoppered bottle nearly full of the water, and put it aside in some dark place where it will experience a temperature of about 70° of Fahrenheit. After allowing it to stand a few weeks, draw the stopper, and apply the nose to the mouth of the bottle; if the water smells in any perceptible degree, it may be pronounced a tainted water.

Means of Purifying Water.

The mechanical impurities of water, or the solid particles rendering it muddy or milky, may in most cases be removed by mechanical means. The two processes for this purpose are *subsidence* and *filtration*.

The effects of subsidence are strikingly seen in the case of rivers that pass through lakes. The Rhône enters the Lake of Geneva almost constantly, in summer at least, of the colour and consistence of pease-soup; it issues from the other end clear as glass and blue as the sky.

The subsidence of solid particles depends on their own weight, as compared with the weight of an equal bulk of water. To favour the process, the most perfect stillness should be allowed. It is expedient to have partitions placed in the subsiding reservoirs at short intervals, more effectually to prevent the agitation of the water. The water should be run off from the top, and not from the bottom. By making the bottom of the subsiding reservoir form a declivity from opposite sides, and providing means to let off the water occasionally from its lowest depth, it is possible to get quit of the subsided mud. It is always found of advantage in clearing water from solid particles, whether by subsidence or by filtration, to mix together streams of different qualities.

There are two methods of filtration in common use. One consists in forming a tunnel, either in a natural bed of sand or gravel by the side or in the centre of a river, and so situated as to become charged with water, which is then pumped up for use. This Natural Filter, first applied at Glasgow, and afterwards adopted at other places, is now believed to be a failure. The tunnel is often found to yield springs of an objectionable quality. A still more fatal objection, and one belonging to the very nature of the construction, is the changing level of the water in the river. It will happen that in hot weather, when water is most in demand, the level of the river is lowest, and the quantity passing through the filter least. The consequence is, that where this filter is employed, it becomes necessary in the summer months to take water from the river direct for the supply of the town.

The other method is to construct artificial filters. This is done by forming a basin, having the floor nearly level, but slightly inclining towards a centre line, and made water-tight by puddling the bottom and sides with clay. On the floor is laid a series of layers of gravel, coarse at first, and getting gradually finer upwards; next a layer of slate-chips or sea-shells, then one of coarse sand, on which is placed the actual filtering layer of fine sand. The depth of this layer is from twelve to thirty inches, that of the entire mass from four to six feet. The water being admitted gently on the top of the sand, sinks down and is conducted by a series of channels, generally of tile-pipes, into the main drain. A filter in a clean state will pass from twelve to eighteen vertical feet of water in twenty-four hours. The solid matter intercepted does not penetrate more than three-fourths of an inch into the sand, so that by removing a very thin film from the surface, the filter is again clean. What is scraped off the top, is capable of being washed and put again to use. 'This process of filtration,' says Professor Clark, 'is efficacious in removing mechanical impurities to an extent that could scarcely be believed without seeing the process.'

The cleansing power of sand can hardly be accounted for on the theory of mere mechanical interception. Though there is no chemical action, strictly speaking, there is no doubt that the attraction of adhesion is at work—a power that plays a greater part in natural processes than has generally been assigned to it.

Some substances manifest this adhesive attraction more strongly than sand, and have therefore still greater efficacy as filters; though practically, and on the large scale, sand is the most eligible. Powdered charcoal has long been known as a powerful filtering medium, attracting and detaining especially organic matter. Animal charcoal, or that derived from burning bones, is still more efficacious than wood charcoal. A filter of animal charcoal will render London porter almost colourless.

According to recent researches, it would seem that loam and clay have similar properties, and may be made available as filters. Professor Way states that 'they have powers of chemical action for the removal of organic and inorganic matters from water, to an extent never before suspected.' The filthiest liquids, such as putrid urine and sewer-water, when passed through clay, dropped from the filter colourless and inoffensive. The clay used was that known as pipe-clay.

Filters for domestic use will be noticed in the number on HOUSEHOLD HINTS.

Softening of Hard Water—Clark's Process.—This is one of the most beautiful applications of science to the arts of life that could perhaps be named. We extract the inventor's own account of it, as given in a paper read before the meeting of the Society of Arts, already alluded to:

'In order to explain how the invention operates, it will be necessary to glance at the chemical composition and some of the chemical properties of chalk; for while chalk makes up the great bulk of the matter to be separated, chalk also contains the ingredient that brings about the separation. The invention is a chemical one for expelling chalk by chalk. Chalk, then, consists, for every 1 pound of 16 ounces, of—lime, 9 ounces; carbonic acid, 7 ounces.

'The 9 ounces of lime may be obtained apart, by burning the chalk, as in a lime-kiln. The 9 ounces of burnt lime may be dissolved in any quantity of water, not less than 40 gallons. The solution would be called lime-water. During the burning of the chalk to convert it into lime, the 7 ounces of carbonic acid are driven off. This acid when uncombined, is naturally volatile and mild; it is the same substance that forms what has been called soda-water, when dissolved in water under pressure.

'Now, so very sparingly soluble in water is chalk by itself, that probably upwards of 5000 gallons would be necessary to dissolve 1 pound of 16 ounces; but by combining 1 pound of chalk in water with 7 ounces additional of carbonic acid—that is to say, as much more carbonic acid as the chalk itself contains—the chalk becomes readily soluble in water, and when so dissolved, is called bicarbonate of lime. If the quantity of water containing the 1 pound of chalk with 7 ounces additional of carbonic acid, were 400 gallons, the solution would be a water of the same hardness as well-water from the chalk-strata, and not sensibly different in other respects.

'Thus it appears that 1 pound of chalk, scarcely soluble at all in water, may be rendered soluble in it by either of two distinct chemical changes—soluble by

being deprived entirely of its carbonic acid, when it was capable of changing water into lime-water, and soluble by combining with a second dose of carbonic acid, making up bicarbonate of lime.

'Now, if a solution of the 9 ounces of burnt lime, forming lime-water, and another solution of the 1 pound of chalk and the 7 ounces of carbonic acid, forming bicarbonate of lime, be mixed together, they will so act upon each other as to restore the 2 pounds of chalk, which will, after the mixture, subside, leaving a bright water above. This water will be free from bicarbonate of lime, free from burnt lime, and free from chalk, except a very little, which we keep out of account at present for the sake of simplicity in this explanation. The following table will shew what occurs when this mutual action takes place:

Agents.		Products.	
Bicarbonate of lime in 400 gallons ...	Chalk............ 16 oz. with	= 16 oz. of chalk	= 2 lbs.
	Carbonic acid 7 oz.	= 16 oz. of chalk	
Burnt lime in 40 gallons of lime-water..................................	9 oz.		

A small residuum of the chalk always remains not separated by the process. Of 17½ grains, for instance, contained in a gallon of water, only 16 grains would be deposited, and 1½ grains would remain. In other words, water with 17½° of hardness, arising from chalk, can be reduced to 1½°, but not lower.

'These explanations will make it easy to comprehend the successive parts of the softening process.

'Supposing it was a moderate quantity of well-water from the chalk-strata around the metropolis that we had to soften, say 400 gallons. This quantity, as has already been explained, would contain 1 pound of chalk, and would fill a vessel 4 feet square by 4 feet deep.

'We would take 9 ounces of burnt lime, made from soft upper chalk; we first slack it into a hydrate, by adding a little water. When this is done, we would put the slacked lime into the vessel where we intend to soften; then gradually add some of the water in order to form lime-water. For this purpose, at least 40 gallons are necessary, but we may add water gradually till we have added thrice as much as this; afterwards, we may add the water more freely, taking care to mix intimately the water and the lime-water, or lime. Or we might previously form saturated lime-water, which is very easy to form, and then make use of this lime-water instead of lime, putting in the lime-water first, and adding the water to be softened. The proportion in this case would be one bulk of lime-water to ten bulks of the hard water.'

It is of importance that the lime or lime-water—that is, the softening ingredient—be put into the vessel first, and the hard water gradually added, because there is thus an excess of lime present up to the very close of the process, and this circumstance is found to render the precipitation of the carbonate of lime produced in the process more easy. The conductor of the process knows when he has added enough of the hard water to take up the last excess of the lime, by applying what is called the silver test. The carbonate of lime when first formed gives to the mixed waters the appearance of a well-mixed whitewash; but in a few hours it subsides and leaves the water above perfectly clear. The softened water thus obtained is stated to have no action on lead pipes or cisterns, as many soft waters have. One ton of burnt lime, used for softening, will produce three and a half tons of precipitate, which forms a very superior kind of whiting, though it has not as yet been turned to any commercial account. The present water-supply of the metropolis, if subjected to Clark's process, would deposit about fifty tons of chalk daily.

The process has been in operation on a large scale for upwards of two years at the Plumstead water-works, near Woolwich, where 600,000 gallons daily are operated upon with the most satisfactory result. The water there, as pumped up from the chalk-strata, has 21¼° of hardness; after the process it has 8¼°. Of this remaining hardness, however, only 1¼° are due to chalk; the other 7° arise from sulphate of lime, on which neither liming nor boiling has any effect. It may be removed by carbonate of soda, which precipitates it as carbonate.

Clark's process is not confined in its effects to softening; it has a decided influence as regards organic impurities. It has been already seen that chalk-water has within itself an active source of corruption. The carbonic acid which it is so ready to part with, favours the growth of plants, and these are followed by animals which soon die, and lead to much impurity. The precipitation of the chalk, for one thing, takes away the source of these impurities, as was strikingly proved by an experiment made by the Plumstead Water-company. They omitted the liming process for a time, and supplied the water to the consumers unsoftened. In a few days, the surface of the water in the reservoirs became covered with masses of vegetation, and gave out a stench of decaying vegetable matter; though nothing of the kind had been seen or felt before. 'Not slow were the consumers in discovering the sudden hardness that had come over the water, nor were they silent under the discovery; and the company gave up their instructive experiment at the end of three weeks.'

As regards organic contamination already existing in water, the precipitated chalk carries a large proportion of such matter along with it. When Thames water was submitted to the process, it was found that the quantity of organic matter had been reduced to one-third of what it was before the lime was added. Nor is it merely the suspended matter that is carried down; the dissolved matter is also reduced. Still, it is not pretended that all the dissolved organic matter is thus removed. Water much contaminated still retains, even after liming and filtering, offensive qualities, and sewage ingredients liable to putrefactive changes. This renders it much to be regretted that the Thames and other contaminated open channels should still be the sources from which the water-companies are allowed to draw the supplies of the metropolis; for though the application of the liming process would undoubtedly improve them, more perhaps than any method of filtering, they can never be rendered desirable, or even safe. 'Even in the water supplied by the Lambeth Company, which is comparatively the purest of the whole, organic productions, dead and living, animal and vegetable, are found in not inconsiderable numbers; and this water furnishes the type of that with which, in 1855, the greater part of London and its vicinity will be supplied, in accordance with the recent Act by which the water-supply of the metropolis was regulated. The metropolis, then, after that year, will still continue to be supplied with river-waters containing various kinds of organic matters, including numerous living productions. Now, that there is no necessity that this should be, has been clearly proved by the case of the Plumstead Water-company, which supplies a water entirely free from living organic productions of every description.'* It is demonstrable that the chalk-strata around London would furnish an inexhaustible supply of spring-water, which, after liming, would be superior even to that of Plumstead.

Natural Process of Purification from Organic Matter.—We have seen that though by means of sand and other filters, or of the liming process, organic contamination of water may be much reduced, there still remains enough to render the water unsafe for use. Is water then, once corrupted with organic matter, hopelessly and permanently so? This question can be answered in the negative. Filthy water has a tendency to purify itself; and this in two ways. In the first place, in any shallow stream of polluted water, such as

* *Appendix to Report of the Committee for Scientific Inquiries in Relation to the Cholera Epidemic of* 1854, p. 271.

the kennels of a street, there may be observed long brushes of a sort of slimy vegetation adhering to every projection of the bottom. All this matter has been disengaged from the water, which thus flows away so much the purer. The second and most effective part of the natural purification consists in the actual decomposition of the impurities. The nitrogen of the decaying matter, then, goes to form nitric acid, which, uniting with bases, forms salts of the class called *nitrates*, of which saltpetre is one. Thus, what was in a state of putrefactive change, offensive to the senses, breeding loathsome insects, and causing dangerous disorders, is changed in course of time into a stable and harmless product. This process is constantly going on in rivers and other waters containing organic matter. Dr Angus Smith found that the amount of dissolved nitrates contained in Thames water at different points from its source to London Bridge, went on increasing as the river became mixed with sewage from the towns on its banks. Nature was thus seen working to counteract the evil. In the Thames, especially near London, the contamination goes on at a rate far beyond the power of natural purification; but it is clear that nature is constantly abating it, and that, but for this process, it would be much greater than it actually is. We can thus easily conceive how a river, very much contaminated with organic impurities at one part of its course, may, after flowing a long way through an uninhabited tract, be quite restored to its natural state.

This process is much favoured and hastened when the water is made to percolate or filter very slowly through beds of earth. Dr Smith found an extraordinary amount of nitrates in some of the London wells. If the filtration has been sufficiently prolonged to convert all the decaying matter into nitrates, the water will be pure, as far as the organic taint and the presence of animalcules are concerned, and will, in fact, be neither disagreeable nor unwholesome, the amount of the dissolved nitrates being unimportant. A knowledge of this purifying process is of consequence in allaying apprehensions as to the impurity of wells and springs suspected of too close proximity to drainage or other cause of pollution. If a tolerably thick bed intervene, the chances are, that a complete purification will be effected during the percolation.

There can be little doubt that part of the purifying effect of artificial filtering takes place in the way now described. Not merely can the grosser particles not get through the narrow interstices of the filter, but impalpable matters are retained by a sort of vegetative adhesion. Dr Smith, again, has proved by direct experiment that decomposing organic matter passed through a filtering-bed is changed into nitric acid. 'A jar, open at both ends, such as is used with an air-pump, was filled with sand, and some putrid yeast, which contained no nitric acid, was mixed with pure water, and poured on the sand, and allowed to filter through. The production of nitric acid was abundant.' It is not improbable that other earthy matters, such as loam and clay, may have a still more decided influence in hastening the formation of the nitrates; and perhaps by imitating more closely the slow mode of filtration by which nature converts surface-water into spring-water, it may yet be practicable to make the most contaminated waters fit for use.

Storage and Distribution.

The engineering principles connected with water-works are touched on in the number on CIVIL ENGINEERING. We have here to consider modes of storing and distributing, as they affect the quality of the water and the comfort and health of the population.

The extent of the storage in reservoirs depends on the nature of the supply. If water is derived from perennial springs, whose minimum flow equals the maximum demand, the storage may be the least possible. If a river is the source, the reservoirs should be large enough to hold such a stock as will carry the consumers over the periods when the river is polluted by rains; they should also be large, on the principle of allowing time for purification by subsidence, especially if artificial filtration be not employed. In places where the supply is obtained from surface-drainage, the practice has been to build reservoirs capable of containing a five or six months' supply, it being necessary to provide against the greatest droughts that ever happen in any season.

The reservoirs should be deep, so as to prevent vegetation; and the distributing or service reservoirs should be roofed.

In distributing water over a town, two different methods have been adopted, known respectively as the *intermittent* and the *constant* systems of supply. On the intermittent system, water is laid on once a day, or once in two days or three days, as the case may be, and fills a tank attached to every separate house, and from this tank the water is drawn off as required. The feeding-pipe of such a tank or cistern is provided with a ball-cock (see fig.), which ingeniously shuts off or admits the supply, as the cistern may be full or empty. On the constant system, no tank is absolutely needed, but the house-pipes are kept constantly charged through their unbroken connection with the distributing reservoir, which must therefore be higher than the highest house to be served. The intermittent supply was until lately employed everywhere in the metropolis; but it is almost universally admitted that the other system is vastly superior in every respect; and, in consequence, all new works are erected on this system. The disadvantages of the intermittent practice have been strongly set forth in all the recent official reports on sanitary improvement: the expense of the erection and repair of cisterns, the trouble requisite to keep them clean, the contamination of the water by the neighbourhood of sources of pollution, the frequent waste of water that occurs, the difficulties imposed on the poorer class of tenements where cisterns are not provided—are a few of the objections urged against this mode of supply. Dr Hassall's examination of the cistern-water of London revealed a frightful amount of pollution—the consequence of placing water already impure in circumstances where the impurity is still further aggravated.

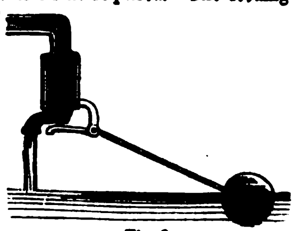


Fig. 2.

One important advantage, arising from the constant system, is the ease with which water can be had in time of fires. The water being supplied at high-pressure, all that is necessary is to affix a hose to the water-plug in the street, when a jet corresponding in height to the pressure is obtained, which can be immediately directed against the fire.

The ratio of the supply to the population varies in different towns. In Edinburgh it is 25 to 30 gallons for each individual; in Glasgow it is 36 to 38 gallons. This includes the water furnished to works of various kinds. The London supply has nearly doubled within the last six years, being now 81,000,000 gallons, distributed among 328,561 houses, which gives 246 gallons per house. The works of the ten companies have cost upwards of £7,000,000. There are 2086 miles of main and branch pipes (exclusive of private service pipes); the subsiding reservoirs cover 141 acres, and the filter-beds 40 acres.

Cisterns, Pipes.—Owing to the action of water on lead already described, it is desirable to avoid the use of that metal in connection with water. With regard to lead *pipes*, if the precaution is taken when the water has stood for any time in them, of allowing the first portions to run off before any is taken for use, little

danger can arise; but either lead *cisterns* should be wholly avoided, or means taken to ascertain whether they contaminate the water; and if so, a remedy should be applied. There are various substitutes for lead as a lining for cisterns. Slate slabs are highly recommended. Gutta-percha is also found to be an easily fitted, cheap, and durable lining. For a few days, the water tastes of the naphtha used in applying the lining; but afterwards no kind of water, not even acids, have any action on the gutta-percha. Pipes of gutta-percha may also be used; they are cheap, and easily fitted up.

Common Wells.—The simplest of all water-supplies is that of a cottage or farmhouse in the country, with a good spring rising to the surface close by. And yet what a poor use is usually made of such a precious boon! The country well is generally a simple cavity to receive the spring, rudely lined, it may be, with stones, but with open mouth, into which dust and dead leaves are blown by every wind, and foul surface-water is trickling from all sides. Being exposed to the light, there is generally a profuse vegetation on the bottom and sides, and, in addition to these impurities, it is further muddied by the dipping in of buckets, often dirty on the outside. Who has not been disgusted, when asking a drink at a cottage, to get water thick with dust and visible impurities, knowing, at the same time, that it might be so easily remedied? A surface-spring should always be covered, and made to issue by a pipe; half a day's labour to create a fall, and a clay drain-tube, will generally convert a filthy puddle into a crystal fount. It is singular to see this blindness to the impurity of water in people otherwise cleanly enough. This is a subject worth the attention of country physicians and clergymen. The evil effects of drinking impure water are not confined to towns. May not the putrid sore throat and malignant fevers that often sweep away whole households in the country, especially in autumn, be partly owing to the cause now pointed at?

Deep wells should invariably be covered, and carefully protected from the infiltration of superficial ooze. The situation of pump-wells is often singularly ill chosen in this respect.

Artesian Wells—so called from Artois, a province in the north of France, where, it appears, the greatest attention has been paid to the discovery of subterranean springs—are distinguished from common wells by the circumstance of their waters rising above the surface, often to a considerable height, and with considerable violence. This fact, that water will rise spontaneously to and above the surface, in certain localities, when bores of various depths are made into the earth, seems to have been long known to mankind. An Alexandrian writer of the sixth century narrates, that 'when wells are sunk in the oasis of the desert, to a depth varying from 100 to 500 ells, water springs from the orifices, so as to form rivers, of which the farmers avail themselves to irrigate their fields.' In more modern times, travellers relate that, in some parts of the Desert of Sahara, the natives sometimes bore the earth to the depth of 200 fathoms, and always succeed in finding water, which flows often up the bores with such force, as to drown those engaged in making the excavations. In China, also, and in European countries, there are proofs of wells of this nature having been early formed.

Artesian wells are common on the continent, particularly in France, which consequently furnishes the finest examples. That of Grenelle, near Paris, is, we believe, the most gigantic, the borings being carried through tertiary and chalk strata to a depth of 1798 feet, or one-third of an English mile. The bore is 20 inches in diameter at the orifice, but is contracted by stages, till at the bottom it is only 7 inches. The bore is lined with iron tubing; and the current, which discharges between 500 and 600 gallons per minute, rises to a height of 30 or 40 feet above the surface. The work was commenced under the superintendence of M. Mulot in November 1833, and finished in February 1844 at an expense of 303,000 francs. In Britain, as well as in France, there are others of large dimensions. In many wells formed on the Artesian principle of penetrating through an impervious stratum to the water-bearing stratum below, the water rises only partially up the shaft or boring, and not quite to the surface. This is the case with the wells of London that are sunk through the stratum of clay. The level in these wells is annually sinking, shewing that this source of supply is already drawn upon to the full.

The geological and hydrostatic principles upon which the forcible discharge of Artesian fountains depends, are sufficiently obvious. The best occur in secondary and tertiary basins, the principle being as follows: Let the annexed section represent a tertiary basin, composed of

Fig. 3.

alternating strata of sand, clay, gravel, and loose sandstone. It is clear that the thick bed of sand and gravel, *a*, lying between two layers of impervious clay, *b* and *c*, can have no outlet for the water with which it is saturated by percolation. It is, in fact, a great subterraneous sheet or reservoir of water, whose maximum pressure is at the bottom of the basin. Below the London clay there is an immense reservoir of this kind. Let a well or bore be sunk in the valley, and the result will be, so soon as the bore strikes the bed of gravel, a rush or jet of water, forcible in proportion to the extent of the bed, and the height to which its sides rise above the surface of the valley. Depending upon these principles, no Artesian well should be attempted without consulting the geologist or mining-engineer. A deflection of the strata, the occurrence of a dike, or some such phenomena, which the geologist alone can interpret, may render abortive years of labour.

Artesian wells are generally formed by *boring*, which is performed in much the same way as a quarryman bores for blasting. The boring-head, or ram, consisting of a mass of iron, with steel chisels fixed in its under side, is made to rise and fall by a rod, or—according to the Chinese method, which is found preferable—by a rope, to which a certain torsion is given. Sometimes the débris is lifted by the ram itself; in other cases a separate auger, or shell pump, is from time to time applied. It is necessary, in soft strata, to line the bore with iron tubing.

Fountains—Jets-d'Eau.

Fountains or jets-d'eau are contrivances by which water is violently spouted or projected upwards in a continuous stream, so as to become at once ornamental, refreshing, and salubrious to the locality in which they are situated. The projecting force is acquired either from the hydraulic pressure of the water at the fountain-head, by the spring and elasticity of a confined volume of air, or by mechanical appliance; but generally by the first. (See HYDRAULICS and PNEUMATICS.) The water is conveyed from the reservoir to the fountain in pipes, and if the orifice from which it issues be directed upwards, it will spout to a height approaching that of the reservoir.

Decorated fountains of this kind were much in request among the Greeks and Romans, not only in their streets and gardens, but also in the courts of their houses; and this fondness for fountains still exists in Italy and the East, where there are numerous elaborate and fanciful designs. The French are also celebrated for their fountains, those at the Tuileries, Versailles, and

St Cloud being superb structures; and indeed, with the exception of our own, most of the large towns of Europe are adorned and refreshed by these contrivances. The most remarkable jet-d'eau in the world is said to be that at Cassel in Germany, where the waters rise from an orifice of twelve inches diameter to a perpendicular height of 200 feet. The source from which it is supplied is at the top of a mountain near by, being about 500 feet above the level of the town. The fountains of the Sydenham Palace are on a grand scale. The jets-d'eau, and cascades of the numerous basins, contain six times the amount of water thrown up by the Grands Eaux at Versailles.

Viewing jets as auxiliaries to health, as well as ornaments, we are inclined to advocate their erection wherever it is practicable. In our public gardens and squares, along promenades, and at the crossing of streets, nothing could be more appropriate and ornamental, independent of the cooling effect which they must exert over the surrounding atmosphere in summer. Where the supply of water is abundant, there is every scope for the ingenuity of the artist and engineer in the designing of fountains—from the most grotesque and fanciful, to the most severely classical conception. Nor is there any reason why small, permanent, or portable fountains should not be more generally introduced into our market-places, shops, and public buildings, where the atmosphere is apt to become heated and contaminated, producing oppression, listlessness, and languor.

BATHS—WASH-HOUSES.

Referring the reader to our article on the Preservation of Health for the sanitary value of personal ablution, we shall here treat of baths as a social arrangement, and of the various mechanical appliances requisite for the establishment of a system.

BATHS OF THE ANCIENTS.

The use of the bath, natural or artificial, has existed, in all probability, from the beginning of the world, since it is founded in the most natural wants of man. The Greeks knew the use of warm baths in the time of Homer. At a later period, they had public baths attached to the *gymnasia*, and the richer families also had baths in their private houses.

The Romans were late in introducing artificial baths. But in the reign of Augustus, they began to give to their warm baths that air of grandeur and magnificence yet to be observed in the ruins which remain. Bathing among the Romans was not a mere dip. It embraced a variety of operations, including gymnastic exercises, performed in a succession of apartments, and with water of all temperatures, accompanied also with the use of unguents and perfumes. At first, the public baths were only opened at two o'clock in the afternoon, and closed at five, the sick alone having a right to enter them at any time; but the hours for bathing were greatly increased in number by the later emperors. The baths were frequented indiscriminately by individuals of all ranks; the noblest and richest persons there finding themselves mingled with the poorest plebeians. Besides baths, the same structure contained theatres, temples, festive halls, promenades planted with trees, academies, libraries, &c.

It was not only the Roman metropolis which contained public and private baths; they existed in all the towns of Italy, and in the palaces of nobles and freedmen; they were found also in all the Roman provinces. The greater number of these magnificent edifices, which, during the most illustrious period of the empire, had constituted the pride and delight of Rome, were destroyed by the vandalism of the barbarian hordes. Those which were not pulled down, were otherwise employed, or, being no longer repaired, gradually fell into ruin. In the middle ages, baths on a more moderate scale were introduced as the ancient structures disappeared. 'The idea,' says Grosley, 'was due to the Arabs, among whom the arts and sciences had found an asylum. The Crusades and commerce had opened up to Europeans the countries which flourished under the rule of this people, and the natural taste for imitation did the rest. The vapour and public baths were, for a long period, as much frequented in Europe as they are at the present day in the Levant.'

MODERN BATHS AND WASH-HOUSES.

Although the increasing use of linen has much diminished the hygienic necessity of the bath, and has occasioned the ruin and neglect of the establishments of the middle ages, yet public attention has not ceased to be directed to the advantages of such establishments—thanks to the salutary counsels of medicine, the progress of civilisation, and the amelioration of the material comforts of the masses. 'Eminent physicians,' says Dr Clark, lamenting our inferiority in this respect to continental nations, 'have endeavoured to draw the attention of the British government to the importance of public baths, and of countenancing their use by every aid of example and encouragement.' Since that physician wrote, the institution of baths has much engaged the public attention. The houses of our higher classes are now invariably fitted up with accommodation for hot and cold bathing; portable baths on the sponge, shower, or plunge principle, are common in the dwellings of the middle classes;* and deficient as we yet are, the last ten years has witnessed the erection of a number of private and public establishments, at which the masses may enjoy a bath for the merest trifle of their weekly earnings. Bathing should be deemed a necessity, not a luxury. The great majority of our artisans and factory-workers are engaged in labour of a kind by no means cleanly, and without daily ablution of some sort or other, disease, injured constitutions, and debased moral sentiments, are certain, sooner or later, to be engendered.

We shall speak presently in detail of public baths; but where steam-engines are employed in connection with cotton-factories or other works, there is usually a certain quantity of waste steam or waste hot water at disposal, which could, at an insignificant cost, be directed into baths for the use of the workmen of the establishment; and we hope this will be done wherever it is practicable. The improved health and cheerfulness of the parties benefited will be more than compensatory for the necessary outlay. We are aware of one instance where seven baths were comfortably fitted up at the small expense of £80, in which the men and women bathe on alternate days, to the number of from thirty to eighty a week—paying a mere trifle to the keeper, who attends an hour and a half each evening, and finds towels, soap, &c., nothing being charged by the proprietors for the original outlay.

Another modern improvement, the public wash-house, calls for mention. In a country where the labouring-classes are in a comparatively easy condition, and thinly scattered, the house is at once the domestic brewery, bakehouse, and laundry, as it is the family sanctuary. But where the masses are densely packed in lanes and alleys, where house-accommodation is dear and limited, where the necessaries of life have to be continually struggled for, and these conventional evils increased, in too many instances, by improvidence, the house is

* In absence of *permanent* baths—which ought to form part of every modern house of any pretensions, just as much as its kitchen or laundry—*portable* baths, now procurable at the iron-mongers in every variety, will be found to be no indifferent substitutes. For a permanent hot bath, the kitchen-range may be constructed so as to have a supply of from ten to twenty gallons of warm water always in readiness, and this, after the original outlay, at a cost almost inappreciable.

but a night-shelter, affording little or no convenience for the necessary operations of the housewife. Independent of this, in point of economy, a public wash-house is preferable to any number of isolated efforts. By co-operation, superior accommodation, better apparatus, and a cheaper and more satisfactory result, can be obtained; and thus the public wash-house, where self-paying and self-supported, may be classed among the co-operative arrangements which characterise the social features of the age. When we consider the amount of fuel required for a kitchen-fire on a washing-day, the time wasted by imperfect arrangements, the inconvenience experienced where the housewife has to wash, dry, and iron her clothes in the one sole room where she has to cook the family meals, and where that family has perhaps to eat, sleep, dress and undress, and perform all the minor offices of life, we can then appreciate the boon which a public wash-house is calculated to confer.

The general nature of a system becoming much more evident when illustrated by specific examples, we will give a brief account of the progress made in recent years in England towards the establishment of baths and wash-houses for the working-classes.

So far as concerns wash-houses, the credit of a reformer is due to Mrs Catherine Wilkinson of Liverpool, who, in a year of cholera, bravely offered the use of her small house, and the value of her personal superintendence, to her poorer neighbours, to facilitate the washing of their clothes at a time when cleanliness was more than usually important. The success attending the exertions of a single individual led to the formation of a benevolent society; and the success of this society led the corporation of Liverpool to the establishment of a small bath-house, containing eighteen private baths, and one vapour bath.

In the month of October 1844, a public meeting was held at the Mansion House, attended by many persons of wealth and influence, to encourage the formation of baths and wash-houses in London; hence resulted an 'Association for Promoting Cleanliness amongst the Poor.' Independently of this movement, a reform had already been commenced by a 'Committee for the Houseless Poor,' who, among other things, purchased or rented an old roomy building in Glasshouse Yard, surrounded by the poor and dense population of the London Docks district. A bath-house and a wash-house were fitted up; baths, cisterns, boilers, cold and hot water, towels, soap, soda, were provided; and the poor were invited to come in, and wash and bathe without expense to themselves. There were also provided pails, brushes, and whitewash, to those who would take the trouble to give a little cleanliness to their poor dwellings. For an expenditure of £900 within a given period, accommodation was afforded for 62,000 bathers, 73,000 washers and driers of clothes, and 15,000 ironers; besides the whitewashing of several hundred rooms and staircases. This was effected greatly through the benevolent exertions of Mr Bowie, a surgeon who applied himself with earnestness to the subject. This gentleman has recorded that women occasionally came many miles to wash their scanty supply of garments at that place: women, too, who had been compelled to *sell their hair* to purchase food for their children. The association, afterwards founded at the city meeting, sought two objects—to induce a wish for cleanliness among the poor; and to render public baths and wash-houses *self-paying*, as a guarantee for their permanency. Having obtained plans and estimates from architects, the association built a model establishment in Goulston Square, Whitechapel; but owing partly to a difficulty in collecting funds, the baths and wash-houses in that locality were not finished and opened until the year 1847; the cost, too, had been so enormously increased by the experiments incident to a new undertaking, that the entire outlay ultimately reached £26,000. In the meantime, another society had succeeded in establishing baths and wash-houses in George Street, Hampstead Road, favoured by a liberal arrangement on the part of the New River Company in the supply of water: this establishment was opened in August 1846. In the same year, parliament passed an act to enable borough-councils and parish vestries to establish public baths and wash-houses, supported by borough and parish rates, if the householders should sanction such a proceeding. In 1847, another act strengthened the former; and the two together contain the necessary clauses for defining the details of the plan. The chief of these clauses are—that the requisite funds may be raised on the security of the poor-rates, at 4 per cent., to be repaid by thirty yearly instalments; and that the minimum charges, for the benefit of the poor, should not exceed one penny for a cold bath, twopence for a warm bath, and one penny per hour for laundry conveniences. The parish of St Martin's-in-the-Fields was the first to take advantage of the new act; and before the close of 1852, six parishes had erected public baths and wash-houses, and in each establishment attempts were made to introduce improvements in the practical details. At the beginning of 1856, the list had nearly doubled. The original free but humble building in Glasshouse Yard had been abandoned; but the model establishment in Goulston Square, and the separate undertaking in Hampstead Road, remained; giving a total of thirteen public baths and wash-houses in the metropolis at the beginning of 1856.

It is not to be supposed that these efforts have been confined to London. Liverpool took precedence in date, and has since worthily maintained her interest in the matter. The baths and wash-houses first established are in Paul Street; the next, opened in 1851 in conformity with the provisions of the new act, in Cornwallis Street; and to these have since been added two others, at George Pier Head and Frederick Street. Hull, Bristol, Birmingham, Preston, Bath, Wolverhampton, Coventry, Plymouth, Chester, Sunderland, Bolton, Macclesfield, Oxford, Maidstone, Exeter, Rotherham, Colchester, South Shields, Dublin, Belfast, Glasgow, Dundee, and other towns, have since adopted a similar course; and it may safely be predicted that borough and parochial baths and wash-houses will increase in number year by year; for if they do not actually pay their full expenses at the low charges framed, the deficiency will be so small as to be practically unfelt by rate-payers.

When the legislature took up the subject, the purpose of the committee appointed in 1844 was in great part answered; but that committee continued to exist until 1855; and the energetic exertions of Mr Cotton, Mr Hawes, and Mr Woolcott, in their capacities as chairman, deputy-chairman, and secretary, were attended with very beneficial results, in drawing the attention of influential persons throughout the country to the advantages of public baths and wash-houses. One report from the committee contains the following highly interesting information concerning foreign countries: 'In consequence of the favourable report made to the French government by the commission appointed to inquire and report on the public baths and wash-houses in England, 600,000 francs were voted by the late National Assembly, to assist the promotion of such institutions in France, after the plan of the model establishment; and a scheme was set on foot for erecting fourteen establishments in Paris, for which 2,000,000 francs would be required. The municipality of Venice contemplate an expenditure there of £33,000 in the erection of baths on the same plan. The Norwegian government have applied to the committee for the plans, &c., of their wash-house at Goulston Square, as a guide for the erection of one at Christiania; and a subscription has been commenced for the erection of baths and wash-houses at Copenhagen. The Belgian government, and the authorities at Hamburg, Turin, Munich,

Amsterdam, Lisbon, and New York, have also been furnished with information on the subject.'

In nearly all the London establishments, which may also be taken as types of those in the country, the characteristic features are as follows: The baths for males and females are on opposite sides of the building, separated in some instances by the washing-room, and in others by the plunging-baths. The separate baths, in large well-lighted and well-ventilated rooms, are shut in by walls generally of slate; and the baths themselves, supplied with fifty or sixty gallons of water for each bather, are either of zinc or enamelled iron. There are two, three, or four classes of baths, charged differently according to the amount of accommodation afforded. At the St Martin's establishment, where there are only two classes of baths, it has been found that the second-class bathers are thrice as numerous as the first. Arrangements, slightly varying in different establishments, afford means for conveying hot and cold water to every bath. In some instances there are tepid as well as cold swimming or plunging baths; while two or three of them afford facilities for shower and vapour baths. Much more interesting, however, are the wash-houses, as examples of a great improvement. The washing-room is provided with numerous small compartments, doorless and roofless, each for one person. Each compartment contains a boiler and a washing-tub, with taps for hot water, cold water, waste water, and steam: all unlimited in quantity, wilful waste of course being guarded against. An American washing-board assists the operations; and a rack-work stand protects the feet. The steam from all the compartments is carried upwards to one great ventilating shaft. The 'wringing' of the wet washed linen is effected by putting the articles into a sort of perforated cylinder, which is then rotated with great velocity; the centrifugal force drives out the water through the perforations and interstices, leaving the linen, though damp, much drier than it can be made by the familiar laundry process. The clothes are then taken to the drying-room, where they are hung on frames or 'horses' in small chambers heated with hot air to about 200° or 210°. At first, great difficulties were experienced in conducting this process profitably, for a current of hot air carried off the value of a great deal of fuel; but a skilful method was at length adopted, and 10,000 or 12,000 articles of washed clothing can now be dried with £1 worth of fuel. In some of the improved establishments there is a drying compartment belonging to each washing compartment, effecting a manifest saving of time to the washers; in some of them, too, there is an ironing-board to each compartment, but the general plan is to have a large ironing-room, well provided with irons, ironing-blankets and boards, and heating arrangements. The charge is from 1d. to 2½d. per hour, according to the class and the accommodation. The amount of time and money saved, and discomfort avoided by the adoption of this excellent system, can only be appreciated by those who know the difficulties under which linen-washing is conducted in the cramped houses of working-people in densely populated towns.

With the presentation of a few figures, we shall conclude this part of our subject. It has been found by actual results, at the Goulston Square establishment, that 37,000 garments—an aggregate of all the usual kinds—belonging to 1370 washers, were washed, dried, and ironed in 3000 hours: that is, each woman, on an average, working about two and a quarter hours, began and finished the washing and ironing of her family stock of twenty-seven articles. Of course this last-mentioned number would be varied according to the station in life of the washer and her family; but taken as it stands, it affords some slight clue to the wardrobe-wealth of the Whitechapel district, so far as regards those who availed themselves of the public wash-houses—especially as it is found that, on an average, each washer washes for four persons. When the model establishment was first founded, the fuel for heating 1000 warm baths cost £3, 15s.; but by successive improvements, this cost was reduced to £1, 4s.* The valuable tables drawn up by Mr Woolcott shew the progressive advance in the baths and wash-houses of the metropolis, between 1848 and 1855—the number of establishments being increased from two to thirteen, and the receipts from about £2800 to £24,500.

The following table shews the ratio between the bathers, the washers, and the receipts, at the thirteen metropolitan establishments, in the year 1855:

	Bathers.	Washers.	Receipts.
			£
Whitechapel, ...	138,843	44,126	2690
St Martin's, ...	101,901	42,903	2210
St Margaret's, ...	70,517	59,516	1728
Marylebone, ...	139,926	23,790	2423
Greenwich, ...	55,210	5,201	897
St James, ...	97,581	40,483	1959
Poplar, ...	45,536	10,909	930
St Giles, ...	157,928	43,118	3501
Bermondsey, ...	79,986	21,267	1542
Lambeth, ...	121,912		2020
Davies Street, ...	63,307	16,074	1255
Belgrave Place, ...	70,101	12,119	1151
Hampstead Road, . . .	76,002	98,133	2191
	1,216,750	417,634	24,527

The whole number, bathers and washers, paid about 4d. each on an average. The following table refers to nine country establishments for the same year, 1855:

	Bathers.	Washers.	Receipts.
Liverpool:			£
Cornwallis Street, . .	114,527		1903
Paul Street, ...	53,491	12,381	906
George Pier, ...	54,460		1911
Frederick Street, ...		16,463	402
Hull, ...	50,113	8,513	573
Bristol, ...	37,907	18,056	629
Preston, ...	27,416	9,704	388
Birmingham, ...	91,214	6,081	1680
Maidstone, ...	32,818	8,875	361

Here also the average is about 4d.

The wash-house part of the scheme does not seem to succeed in Scotland. In Glasgow, the wash-houses have been given up; the baths, on the contrary, are flourishing; one of the two public establishments had, in 1856, 40,000 bathers, and is more than self-supporting. The case is much the same at Dundee and Aberdeen.

SEWERAGE AND DRAINAGE.

As efficient means should be taken to secure for our towns and cities a regular and abundant supply of pure water, so ought there to be a regular system of emission for that which is foul and waste. The rain which falls on our roofs and streets, and the waste water of our houses and public works, with all the animal and vegetable matter wherewith they are impregnated, must be regularly and speedily carried off, otherwise stagnation and putridity ensue, deleterious effluvia arise, and are inhaled by the inhabitants, and disease, suffering, and death are the inevitable consequences. The most obvious method of discharge is by open gutters; but as these are offensive and unsightly, the great object, both in ancient and modern times, has been to establish a system of underground sewerage.

Among ancient nations, the Romans carried underground sewerage to the greatest perfection; and it is worth while, in these days of sanitary preachments, briefly to glance at their *cloacæ*—a term which includes

* Might not still greater economy be effected *by transferring the heat from the used water to the clean*, on the principle explained in the number on WARMING?

not only the larger sewers which led to the Tiber, but the small drains or pipes of wood or clay leading into these. The whole city was thus intersected by subterranean passages. The most celebrated of these drains was the *Cloaca Maxima*, the construction of which is ascribed to Tarquinius Priscus, and which was formed to carry off the waters brought down from the adjacent hills into the Velabrum and valley of the Forum. The work is evidently of great antiquity. The arch of this cloaca is semicircular, and formed of three rings of voussoirs, as shewn in the annexed cut, being 14 feet in width, and 32 in height. The blocks are hewn, and joined together without cement. The erection of such spacious sewers to take off the drainage-matters of houses which were mere huts in comparison, contrasts painfully with the indifference shewn on these points by modern governments. In England, some years ago, the commissioners appointed to inquire into the Health of Towns reported that of fifty towns visited by them, forty-two were decidedly bad, and that scarcely one could be pronounced good as regards the state of the drainage. The importance to the health of the community of a good system of drainage, is too obvious to need much comment. Dr Southwood Smith, an eminent authority in all sanitary matters, says, he believes 'the immediate and direct cause of fever to be a poison generated by the decomposition of animal and vegetable matters.' He instances the case of Lambeth Square, where thirty-seven houses, previously visited by cholera and typhus, were, by the substitution of water-closets and drain-pipes for privies and cess-pools, freed from the recurring typhus, and escaped the following visitations of cholera that ravaged the surrounding streets.

Fig. 4.

The chief points connected with the construction of the main sewers of a town are noticed in the number on CIVIL ENGINEERING. We have here to speak of the drainage of the individual houses.

While the street-drains or main sewers are built of brick or other materials, the small drains for the separate houses may consist of earthenware tubes. The tube-system was at one time strongly advocated both for mains and branches; but experience has proved that the employment of earthenware tubes is not advisable where a channel of above twelve inches diameter is required. Within that limit, and therefore for house-drainage, pipes are allowed on all hands to be preferable in every way to brick-drains.

Mr Bazdgette, engineer to the Metropolitan Commissioners of Sewers, finds that a drain-tube of nine inches diameter will be sufficient to receive the drainage of from three to six small cottages or houses; and that each separate house should have a drain-tube of six inches diametor; this being the minimum in all cases. The thickness of pipes—an important point—has been fixed on by the commissioners at ¾ inch for 6 inches diameter; 1 inch for 9 inches; and 1½ inch thick for 12 inches diameter.

Great care is required in properly joining the pipes, so as to prevent leakage. The joints are of various kinds, and are cemented with Roman cement or with puddled clay. Underground work of this kind is very apt to be *scamped*, as it is called, and workmen require more than ordinary supervision. If the pipes are not properly bedded, they are liable to break, and either cause a complete stoppage, or soak the soil with the sewage.

In every system of sewerage, a certain amount of continuous fall is of course necessary—the greater the better. The descent of the water is the moving power; and the filth is better carried off the more abundant the supply of water and the more rapid the current. All the sullage-water of domestic operations should be delivered into the sewers, and not allowed to escape otherwise into the soil. The operation of *flushing* consists in fixing in the sewers gates or sluices, which, when closed, cause the ordinary flow of water to accumulate above them; and when a sufficient quantity is collected, they are thrown open, and the rush of water so caused is sufficient to sweep off the deposits.

One of the most important points connected with house-drains is, how to prevent the foul air, generated in them and in the street-sewers, from entering the house. This is the object of what are called *stench-traps*. One form of this contrivance is that known as the *bell*-trap, usually placed over a sink for admitting surface-water into a drain below. A metal vessel, represented in section in fig. 5, has a cover, *aa*, perforated with holes, to the under side of which is attached a bell or inverted cup, *b*. A tube, *d*, communicating with the drain, rises partly within the bell; and when water pours through the covering, and rises to the level of the tube at *cc*, it escapes into the drain; while foul air rising through *d*, is retained by *b*, and cannot escape without forcing itself through the water and under the edge of the bell—which it will only do under pressure. The *syphon*-trap, fig. 6, is also much used: *d* is the basin of a water-closet, connected with the tubular drain *a*, by the pipe *bb*. On this pipe, below the floor-line, *e*, there is a bend, *c*, which always retains a portion of water, and cuts off the entrance of air from the empty part of the tube.

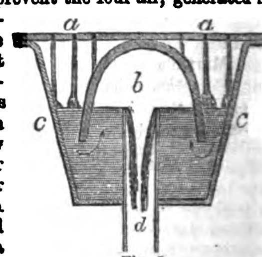


Fig. 5.

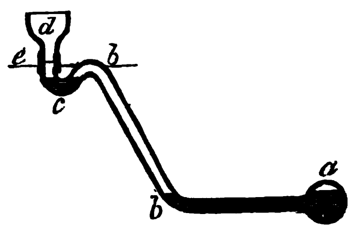


Fig. 6.

But it has been too much forgotten that these traps are efficient only when the air in the drains and pipes is under no extra pressure—a condition which is often wanting. In fact, whenever any part of the pipe or drain below the trap is filled with water, as represented in fig. 6, there must be a regurgitation of foul air into the house every time that water flows down the pipe *bb*; for the pent-up air must escape some way, and it is easier to force its way through *c*, than in the other direction. Any extraordinary rush of water into a drain—above all, the operation of flushing the street-sewers—causes the resistance of the stench-traps to give way, and forces poisonous gases into the houses. To remedy this evil, drains require to be ventilated—that is, to have communications made with the external atmosphere, wherever the air in them is liable to become pent up. This point has been sadly overlooked. The following is the recommendation of the General Board of Health: 'Whenever a water-closet, even with the best sort of water-trap, is introduced into a house, it will be well to provide an escape into the outer air. When several soil-pans or sinks from the apartments of a large house are discharged into a common soil-pipe or vertical main, the main should be continued up to the roof, and opened to the air, and, if practicable, it

should be carried near the chimney. Pipe-sewers must also have ample ventilation provided at all available points. If the air is confined, it is most dangerous when it breaks forth, which sooner or later it will do.'

In towns where there is a proper system of sewers, the house-drainage is of course conducted to the common sewer; there should be no intermediate place of deposit, as a cess-pool. In no case, and under no plea whatever, should these pits of poison and pestilence be permitted. Let them lie open in any degree—and it is impossible to have them hermetically sealed—and they are for ever giving off their noisome and noxious exhalations: they saturate the adjacent soil with their offensive contents; and there is no possibility of preventing the evil without the constantly recurring expense and annoyance of emptying them. The rudest open gutter is preferable in comparison; for it is sure to force itself upon the attention, while the cess-pool, 'out of sight out of mind,' is steaming and fermenting with the most subtile and deadly gases.

In suburban districts, where sewers are not yet constructed, or in the case of isolated houses in the country, the final place of disposal of the drainage-matter must of necessity be some receptacle near to the house. This, however, should never be an open cess-pool, but a closed air-tight liquid-manure tank. The bottom should be an inverted arch, the sides carefully built in, and all the brickwork set in cement—the object being to have it water-tight, so that the liquid may not permeate to the surrounding soil. The cover should be arched, if of brickwork, and provided with a man-hole door as air-tight as possible. A form of sewage-tank on the principle of the upward filter is illustrated in the annexed wood-cut. The drainage enters by the pipe, *c*, into the lower part, *aa*, of the tank, and rises through a false perforated bottom, covered with peat-charcoal, or other absorbent, *ee*, which absorbs part of the fertilising matter; and the liquid is pumped off the top for agricultural or horticultural irrigation. A ton of peat-charcoal is, in a few weeks, transformed into a ton and a half of valuable solid manure, easily removed.

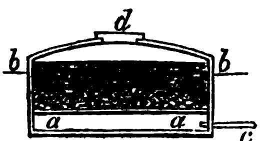


Fig. 7.

How the sewage of towns ought to be disposed of, is a vexed question. Hitherto, the easiest way has been taken—to lead it, namely, into a river or into the sea, and there leave it to shift for itself. But this rough-and-ready plan cannot much longer be tolerated. In the first place, the feeling is growing that our rivers and streams, whose office is to freshen and beautify the country, ought not to be turned to this 'vile service,' which, in populous districts, is rendering them mere abominations. It is questionable, too—if not in law, at all events in morality—whether one town has a right, for the sake of mere economy, to get rid of the nuisance of its own refuse by throwing it into a public river, and thus transferring it to its neighbours below. There is, again, the economical view of the matter. Dirt has been happily defined to be, 'valuable matter in the wrong place;' and it has been proved, again and again, that the sewage of our towns, which does worse than run to waste in our rivers and seas, would, if transferred to the farmer's fields and meadows, be worth millions annually. The question is, how to make this transfer economically and without creating a nuisance. This is one of the most important problems in social economics. Where the situation admits of it, the readiest application of town-sewage is to use it in a liquid state for meadow irrigation. By this means, a tract of several hundred acres of land lying between Edinburgh and the sea, is rendered worth, in some instances, £56 an acre; the grass is often cut nine and ten times a year. At Leicester, Mr Wicksteed, by a process in which he employs cream of lime, separates the fertilising matter of the sewage in a solid form, dismissing the fluid part nearly as pure as the average drinking-water in London. The quantity of dry solid sewage separated in nine months, during the year 1856, was 3000 tons, from three and a half million tons of liquid sewage.

The difficulty of getting rid of the enormous mass of water with which sewage is diluted, is leading an increasing class of sanitary engineers to the opinion, that the refuse-matters of human life ought not to be diluted with water and carried off by sewers, but collected in disinfecting liquids, which would convert them into chemical compounds—inoffensive, and yet valuable as manure. 'As chemistry,' says Mr W. B. Adams, 'has been successful in converting filthy potato-oil and coal-tar into delicate perfumes, it is no doubt chemically possible to convert all the waste material of a household into an innoxious and not unpleasant substance. Two considerations are requisite—first, that it be cheaply done; secondly, that it may not diminish the value of the materials as a manure, by locking up, as it were, the ingredients so firmly as to render them insoluble in the ground for the purposes of vegetation. In this mode, and by no other mode—by chemical conversion, and not by mere mechanical transport—must the ultimate purification of our cities be brought about.'

ABATTOIRS—MARKETS.

The situation and construction of abattoirs or slaughter-houses, and market-places, are intimately connected with the supply and emission of water, and deserve somewhat more than a passing notice.

Abattoirs.—Presuming that every one is less or more acquainted with the operations of the common slaughter-house, it must be evident that these establishments ought to be situated at a distance not only from the denser portions of our towns, but also from the markets or stalls where the meat is exposed for sale; and that they ought, beyond every other place, to be liberally supplied with water. So much filth and garbage of a rapidly decomposing kind is necessarily associated with them, that without an absolute flush of water, and stringent regulations as to its application, they are apt to become centres of the most noisome nuisance and disease. Notwithstanding these facts, which are but too lamentably apparent in all our large towns, yet as a country have we done very little towards the establishment of abattoirs to which the animals might be led quietly, and without danger to the inhabitants, where their carcasses might be dressed with regard to cleanliness, and where the offal might be sluiced away, and collected in such a manner as to become of value to the agriculturist. Our neighbours on the continent are infinitely before us in this respect. The Emperor Napoleon, about the year 1810, ordered five of these establishments to be commenced in different suburbs of Paris; they were executed at the cost of the city, and contained 240 slaughter-houses in all. To each of the abattoirs are attached houses for the melting of tallow; reservoirs, and water laid on by lead pipes wherever required, every means for cleansing, stables and sheds for the use of the butchers, enclosures for the cattle, and apartments for the superintendents. A vaulted sewer receives and carries away all superfluous water; there are also buildings for preparing tripe, &c. The slaughter-houses themselves are formed of walls of wrought-stone, and are sixteen feet wide and thirty-two feet in length. Each has two entrances—one in the yard, by which the animal enters; the other in the outer side, to permit the removal of the meat, &c. Each stall is provided with a supply of water for cleansing, with a drain, and a windlass and pulleys, by which the carcass can be drawn up to be flayed. Other

towns in France have similar abattoirs; and so have Mantua and Brussels.

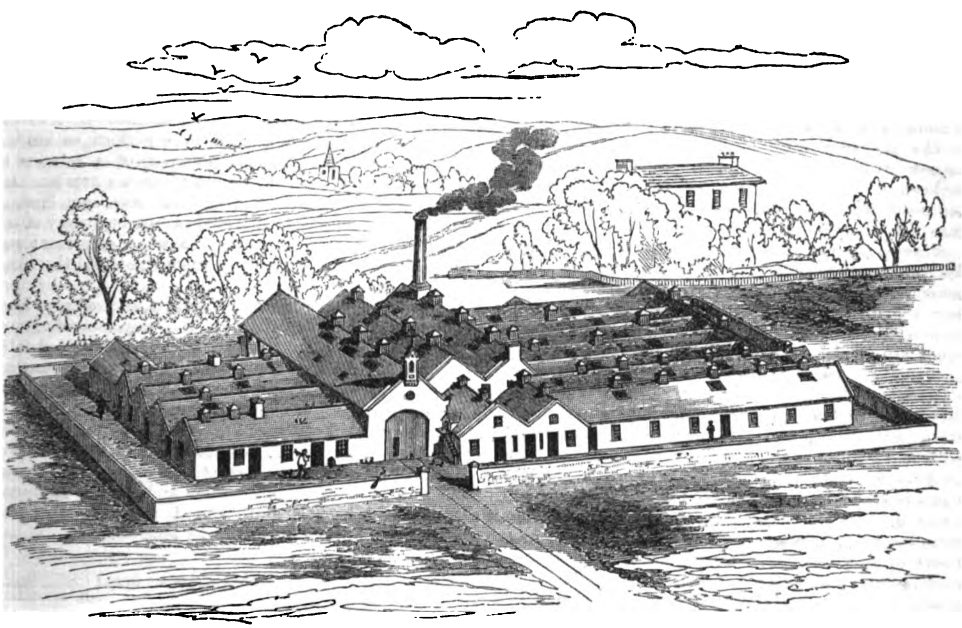
It is much to be wished that some general arrangement like the above were adopted in all our large towns and cities, which at present, so far as the slaughtering of animals and the exposing of their carcasses are concerned, are deficient in the extreme. With the finest animals in the world, the largest consumption of butcher-meat, and every facility for the construction of proper shambles, this department of our economy is conducted in a manner at once obnoxious to health, humanity, and decency. What has been lately effected in London, will presently be noticed.

Markets.—Leaving it for others to decide whether the existing shop-system of our large towns or that of the Oriental bazaar be the more convenient, there can be little doubt that concentrated and commodious market-places for the sale of butcher-meat, fish, poultry, vegetables, fruit, and the like, are highly advantageous for the bulk of the population. Legitimate competition is encouraged, fraud more easily detected, a better choice afforded, and a uniform system of inspection and regulation obtained, which would be utterly impracticable were each country supplier of the raw produce and each town retailer to follow his own isolated plan. Market-places have accordingly been established in all our large towns; but in most cases they are little better than a collection of open stalls, with little regard to arrangement, supply of water, sewerage, shelter, or ventilation. It is true that London, Liverpool, Newcastle, and Aberdeen can boast of commodious, we were about to say magnificent markets; but these are the exceptions, not the rule of the United Kingdom.

Market-places possessing these requisites are common on the continent. Those of Italy—Naples, Florence, Bologna, &c.—are highly spoken of. They are in general lofty airy structures, with light roofs supported on colonnades; have paved areas, are well supplied with water, adorned with fountains, and are easily cleaned. The markets of France are also set down as models, especially the new ones of Paris, in which thorough cleanliness, and a systematic arrangement of the articles exposed, are rigidly enforced. Of our own markets, we have instanced those of London, Newcastle, Liverpool, and Aberdeen, as the most unique and systematic. Those of London are—Covent Garden, for the supply of vegetable produce; Pentonville, for livestock; Leadenhall, for poultry and game; Mark Lane, for corn; Billingsgate, for fish, and the minor depôts of Whitechapel, Newgate, Farringdon, and Hungerford. In illustration of these busy centres, that of Covent Garden may be taken as a fair example. It derives its name from the circumstance of there having once been a convent, with its garden, on the spot which it now occupies. The site of the market, which is spread over two acres of ground, is the property of the Duke of Bedford. Previously to 1830, the booths or stands in the market consisted of rough-looking, slightly built sheds; but in 1828 the legislature interfered, and the present market was built, at an expense of about £50,000; and most ample has been the return received for this money. It is understood that, reckoning rents, and tolls on articles sent to the market, the yearly revenue from Covent Garden market is from £12,000 to £15,000. The rents vary according to the situation of the different shops and stands. Shops in the middle or best part of the market, possessing a little accommodation in the story above, individually bring rents of from £80 to £110 a year. On all wagons, carts, and other vehicles bringing goods to the market, there is toll, varying according to the nature of the articles brought. The open spaces are occupied with various sorts of vegetables, &c., the occupants paying a certain rental per day. This rental varies, according to circumstances and according to situation, from one shilling to fourpence per square foot.

The most recent and important change effected in the markets of the British metropolis has been the formation of the new cattle-market at Pentonville or Copenhagen Fields, in substitution of the very ancient market held in Smithfield since the Norman times. All the numerous improvements wrought at Smithfield failed to render it a fitting locality for a cattle-market in the middle of the vast metropolis; and accordingly, in 1851, an act of parliament was obtained, to enable the corporation to build a new market at the northern margin of London. This establishment, opened in 1855, is unquestionably the finest cattle-market in the British dominions—probably in the world. About seventy-five acres of land were purchased, at a cost of £60,000; and this charge, with the cost of the works and buildings, have raised the total outlay to more than £400,000. About fifteen acres have been appropriated to the market, fifteen to the lairs; and the remainder leaves an ample area for future contingencies. We quote the following from Dodd's *Food of London:* 'The market itself forms a square area, paved throughout with granite, surrounded by a handsome railing with gates, ornamented with a lofty clock-tower in the centre, and provided with an abundant supply of water. In its present state, it could accommodate 36,000 sheep, 6400 bullocks, 1400 calves, and 900 pigs; but whenever it may be needed, increased accommodation may speedily be provided. The area is divided into four nearly equal portions by two broad avenues, crossing each other at the centre; at which point, surrounding the clock-tower, are offices for bankers and others—designated "Bank Buildings." The cattle occupy the eastern sections; the sheep, calves, and pigs are placed in the western. The cattle and sheep pens are conveniently arranged in relation to access and to supply of water; while covered sheds, alongside of which butchers' carts can draw up, are provided for the calves and pigs. Everything that can conduce to the convenience of buyers and sellers, and to the lessening of suffering to the animals, seems to have been thought of by Mr Binning, the city architect. The encircling adjuncts to the market comprise—on the north, two large hotels, with shops on the ground-floor, sheds for the reception of butchers' carts, and a large area of ground available for useful purposes hereafter; on the south, lairs or covered sheds for cattle, *abreuvoirs* or long drinking-troughs, public and private slaughter-houses, and a convenient space for railway approach; on the east, two large taverns, and a space reserved for a hide-market and other purposes; on the west, lairs and abreuvoirs for sheep, and three taverns; lastly, at the extreme south-east and south-west corners are two large spaces available for future slaughter-houses.' At this market, on the great market-day about a fortnight before Christmas in 1855, there were 30,000 head of livestock sold, mostly for consumption on and about Christmas-day.

The slaughter-houses attached to the fine market above described are in all respects well arranged; but they are few in number, and have not yet become a marked feature in the new system. The London slaughter-houses are still, as they have been for many ages, chiefly in the neighbourhoods of Smithfield, Newgate Street, Leadenhall, and Whitechapel: they have undergone improvement, under a licensing act that came into operation in 1856; but they are still, and must be, as long as they remain in such totally unsuitable localities, a disgrace to the British metropolis.



Isometrical View of Covered Homestead.

AGRICULTURE.

MAN is the sole inhabitant of the earth that selects, for the purposes of cultivation, other plants than what the soil naturally brings forth. He has found the earth, in almost every clime, covered with vegetation, yet this often yields little that is fitted to satisfy his wants. The spontaneous growth of nature affording but a limited quantity of food for man, he supplements the supply by capturing the wild animals, which often feed upon what is unsuited for his sustenance. Sometimes, however, the most fertile lands under luxuriant forests, or other natural vegetation, only support a small number of animals. In the most favourable circumstances, a given area of territory cannot maintain many of the human family, so long as they depend upon the natural vegetation or on the chase. It is only after those plants which yield man an abundant supply of food are selected and made the objects of cultivation, that population augments, and civilisation obtains, the primary condition of its existence.

It is therefore one of the chief objects of cultivation to extirpate those plants which naturally occupy the ground, but which do not yield man the particular kind of produce he requires. The earth is covered, in its natural state, by those plants whose habits are best adapted to the climate, and to the chemical and physical nature of the soil. In temperate latitudes, the *cereals*, or corn-bearing grasses, have always been the chief plants from which civilised man has drawn his subsistence. But excepting in a very few spots, none of these are found growing in a wild state. To give full possession of the ground to the cereals, man must wage a perpetual warfare with the indigenous plants which are ever ready to spring up and occupy the ground.

It was a profound observation of Adam Smith, and one that ought to be particularly borne in mind in treating of the *rationale* of agricultural processes, that 'the most important operations of agriculture, seem intended not so much to increase, though they do that too, as to direct the active fertility of nature towards the production of the plants most profitable to man. A field overgrown with briers and brambles may frequently produce as great a quantity of vegetables as the best cultivated vineyard or cornfield. Planting and tillage regulate, more than they animate, the active fertility of nature.' The truth of this proposition is obvious when we reflect, that although there is no ploughing, no manuring, no rotations in the fields of nature, yet vegetation is as luxuriant as in our well-tended cornfields. To yield such results, the plants of nature must possess certain advantages over those which man cultivates. To comprehend the nature of these differences in the requirements of plants, and to enable us more readily to understand the philosophy of the practices of agriculture, the sciences connected with that art will each shortly occupy our attention.

CHEMISTRY OF AGRICULTURE.

The elementary substances occurring in plants, whether wild or cultivated, are oxygen, hydrogen, nitrogen, carbon, sulphur, phosphorus, chlorine, iodine, bromine, fluorine, potassium, sodium, calcium, magnesium, aluminum, silicium, iron, manganese. These eighteen elements are rarely all combined in one plant. It is supposed

that certain of them can be substituted for one another. Thus, sodium and potassium, being somewhat similar in their nature, are sometimes found in varying proportions in the same kinds of plants that have grown on different soils. But the presence of many of them is indispensable, and there can be no substitution in their case. In this position stand the first-named six elements, which play a more fixed part in the economy of vegetation.

The principal mass of all plants is made up of oxygen, hydrogen, nitrogen, and carbon. When a plant is burned, these elements are driven off in the form of gases, and the other elements that had entered into its composition remain as *ash*. It has been customary to call the four elements that disappear by combustion, the *organic elements*, and those that remain in the ash, the *inorganic elements* of plants. But the distinction is without ground. All the elementary substances that are constantly found in a plant, must be considered as necessary parts of its structure or organism, and, in this position, are all equally organic.

With the exception of oxygen, none of the elements found in plants are taken up in the elementary state, but only in a state of chemical combination with other elements. Thus carbon by itself is not food for a plant; it must first be united with oxygen, forming carbonic acid, and in this state it is readily imbibed. Similarly, plants do not take up simple nitrogen, but nitrogen combined with hydrogen, in the shape of ammonia. The substances thus taken up as food by the plant, become united by means of its vital action into definite chemical compounds, called *organic* compounds, because they exist or are formed only in organised beings. Chemists, however, have now very generally adopted the views of Liebig, that the compounds which constitute the food of plants are all inorganic. The inorganic substances, carbonic acid, water, and ammonia, with the alkaline and earthy substances found in the ashes of plants, are now regarded as their only nourishment.

Though plants differ greatly from one another in appearance, and in the physical structure and properties of their substance, yet, when subjected to analysis, they are found to be very similar in composition. The organic compounds of plants may be divided into two great classes—nitrogenous and non-nitrogenous; that is, those which contain nitrogen, and those which are devoid of it.

We know little or nothing of the chemical processes that take place in the interior of plants during their growth. The manner, indeed, in which the particular compounds are determined is still involved in complete mystery. Liebig, however, with his usual sagacity, has pointed out that phosphorus and sulphur are always associated with nitrogenous matter, and that the alkalies and earthy bases direct the formation of substances devoid of nitrogen.

The growth of all plants takes place by the formation of cells, and the nitrogenous structure of cells precedes the non-nitrogenous. In all probability, it is for this reason that phosphates act so favourably on the growth of some plants when applied as manure at an early stage. By phosphates assisting in the formation of the cells of the rootlets of plants, rapid growth is induced. The plants are put in possession of the soil more quickly by obtaining a ready supply of phosphates, and thus obtain the other matters which are fitted for their growth. This chemical point will be more fully treated when we come to other branches of our subject.

The nitrogenous substances found in plants and in animals are usually of the same composition, though they differ in their form. All kinds of wood contain quantities of nitrogenous or albuminous matter, which is identical with the muscle of animals, but most frequently it is not in a fit condition to be assimilated by the larger class of animals. An oak-tree, with its acorns, is composed of nearly the same elements as a ripened plant of wheat. An acre of oaks, too, will often yield, without tillage or manure, as much nourishment for man as an acre of wheat. It was one of Jethro Tull's soundest observations, but which at the same time was entirely against his own theory of vegetable nutrition, that 'men till the ground because tillage procures them better food than acorns.'

It has been truly said by Dr Anderson, that as the analysis of plants has become more perfect, so has the difficulty of explaining the necessity of a rotation of crops, on mere chemical grounds, become greater. Indeed, as already indicated, the fact has been brought out, that not only the cultivated plants, but many of the wild, are composed of nearly the same elements; and as a matter of course, they must feed on the same substances.

The analyses of the ashes of plants by Professor Way, contained in the volumes of the Royal Agricultural Society, put this in a strong light. The subjoined table exhibits the quantity of the alkaline and earthy matters found in an acre's produce each of wheat, turnip, flax, mangel-wurzel, beans, and maize. The wheat-crop is reckoned at 28 bushels of grain and 18 hundredweights of straw; the turnip at 20 tons of bulbs and 4 tons of tops; the flax at 20 bushels seed and 2 tons of straw; the mangel at 20 tons of bulbs and 4 tons tops; the bean at 35 bushels grain and 1 ton of straw; the maize at 48 bushels grain and 1½ tons of straw.

	Wheat.	Turnip.	Flax.	Mangel.	Bean.	Maize.
Silica, . pounds,	84	13·2	22	13	3·17	36
Phosphoric acid, "	20	45·	25	21	16·	31
Sulphuric acid, "	4	50	8	22	3	6
Lime, . . "	8	90	51	21	25	13
Magnesia, . "	6	14	12	22	6	12
Peroxide of iron, "	0	—	9	—	0·69	3
Potash, . . "	22	140	59	133	64·	56
Soda, . . "	2	33	6	70	3	—
Chlor. of sodium, "	—	57	20	160	13	3
	146	442	212	462	144	160

The marked feature in this table, is the large amount of alkalies and alkaline earths that the fallow crops, turnips and mangel-wurzel, require in comparison with wheat. Silica enters largely into the composition of wheat-straw, and only sparingly into other crops. The turnip has more phosphates in a crop of twenty tons than any of the others in the table; still, the beneficial influence which phosphates often have when applied as manure to this crop, must be attributed to other causes than to the mere extra quantity in their composition.

Soils can be fertile only if they contain a supply of alkalies and earthy bases sufficient for the full development of plants. But soils become exhausted for many kinds of plants, even when they contain abundance of these elements. If a vigorous vegetation can be promoted by applying ammonia, it indicates that there is abundance of earthy matter for the wants of the particular vegetation. Some plants are more dependent than others on a supply of carbonic acid and ammonia in the soil. Such differences in the requirements of plants lead us to treat of

THE PHYSIOLOGY OF AGRICULTURE.

Carbonic acid, water, and ammonia, which constitute the chief food of all plants, exist in the atmosphere and in the soil. Plants have the power of obtaining them from both these sources—taking them from the atmosphere by means of their leaves, and from the soil by their roots. Carbonic acid and ammonia become fixed in the leaves of plants by virtue of chemical affinities directed by the vital agencies. Two essential conditions of atmospheric absorption are—first, that the soil supply the requisite quantity of moisture; second, abundance of the substances found in the ashes of plants. These conditions being favourable, the amount of carbonic and

ammonia that a plant will draw from the atmosphere will, other things being equal, depend upon the surface of leaves which it exposes to the air during the growing season. An oak-tree, which has an immense surface of leaves exposed to the atmosphere, has greater facilities of abstracting carbonic acid and ammonia than the wheat or turnip, which must first receive a liberal supply of these substances from the soil, in order to form a surface capable of taking food from the aërial medium.

Plants like wheat and turnips are said, naturally enough, to be great exhausters of the soil, because they cannot be raised unless they are fed or manured by materials yielding an abundant supply of carbonic acid and ammonia. It is now generally admitted that a liberal supply of substances yielding nitrogen is essential for raising a maximum produce of grain and root crops. At the same time, it must be borne in mind that nitrogenous manures have a beneficial influence on all our cultivated crops, but some crops are more dependent on a supply than others, and some can digest or assimilate more in a given time.

The first great physiological distinction which may be drawn with respect to the capabilities of plants for drawing a supply of food from the atmosphere is, that *annuals* are much more dependent on a supply of carbonic acid and ammonia in the soil than *perennials*. Indeed, comparatively speaking, annuals exhaust, but perennials ameliorate the land.

Annuals rarely impart a feature to the natural landscape, for perennial vegetation almost everywhere occupies the ground. Perennials have not everything to do in one season, for every year strengthens their hold upon the soil, and increases the surface of leaves which they expose to the air. Perennial vegetation, therefore, often exhibits considerable luxuriance when the soil is deficient in matters yielding carbonic acid and ammonia. On the other hand, the larger class of annuals are never found growing luxuriantly on soils deficient in substances yielding carbonic acid and ammonia. In fact, annuals must be so far regarded as a sort of parasites. A poor soil may have the effect of causing a perennial to delay the production of its seeds; but through its economical habits, it will thrive where an annual would starve. The thriftless annual casts away its roots and stems, which, as they decay, are liable to be washed out of the soil by the rains. A perennial plant, however, may be said to be manured, and well manured too, by its roots and branches, which are kept in a vital state. The habits of growth in perennials are thus of a very economical character.

It is annual plants that principally supply man with food in the temperate latitudes. Their grand deficiency in having no perennial roots and branches must be made up by manuring. As a general rule in husbandry, if an annual succeed an annual in the rotation, though it may be raised for the purpose of ameliorating the soil, it requires to be liberally manured. Thus all our fallow crops, such as turnips, mangel, beans, and potatoes, are freely treated by substances yielding carbonic acid and ammonia. These crops being all annuals, are particularly dependent on a supply of such substances.

On the other hand, when our fields become exhausted by the growth of cereals, we restore their fertility by abandoning their cultivation for a time, and allowing them to accumulate vegetable matter through the growth of perennials, such as grasses or clovers. Annuals succeeding perennials, perennials succeeding annuals, has been the primitive rotation—when a rotation was necessary—in all countries and in all ages. It was Liebig who first demonstrated, that the effect of pasturing land was, to accumulate ammonia from the atmosphere.

The more nearly that an annual approaches in its habits to a perennial, the less dependent it is upon a supply of carbonic acid and ammonia in the soil. So long as an annual plant puts forth fresh leaves, it is capable of drawing upon the food contained in the atmosphere, and therefore less dependent on a supply furnished to its roots. Thus a pea, which puts forth fresh leaves and blossoms, and even ripens fruit at the same time, can draw more largely from the atmosphere than the wheat-plant, which puts forth no fresh leaves after it flowers, when the most of the leaves lose their vitality. The wheat-plant, being in a great measure devoid of foliaceous surface, must be liberally supplied by manure, and hence it has the character of being an exhausting crop.

As already stated, perennials, as a general rule—particularly true with respect to the larger kinds—are less dependent on a supply of ammonia and carbonic acid in the soil than annuals. Viewing the physiological aspects of the question, the principle may be stated so as to embrace annual and perennial vegetation in the following terms: *Plants are less dependent on a supply of carbonic acid and ammonia in the soil when their vegetative powers coexist, as they do in grasses and clovers, with their flowering and seed-forming processes.*

As was pointed out by Liebig, the atmosphere contains a supply of carbonic acid and ammonia sufficient for all the plants that grow upon the surface of the earth, whether wild or cultivated. This proposition is rendered evident when we reflect that an acre of land under a forest assimilates as much carbon, oxygen, hydrogen, and nitrogen during the growing season, as an acre under any of our crops, such as turnips or clover. It is well to bear in mind, therefore, that the necessity of manuring our fields with substances yielding carbonic acid and ammonia, does not arise so much from a deficiency of those substances in the natural source of supply, the atmosphere, as from an inherent deficiency in the plants cultivated for drawing largely upon this source. The vegetation that covers the surface of the earth in a state of nature, possesses greater facilities for abstracting a supply of carbonic acid and ammonia from the natural source, than most of our cultivated crops, which, consequently, must be manured.

Perennials not only possess greater facilities of abstracting food from the atmosphere, but they have greater facilities of abstracting it from the soil. By forgetting this very obvious principle, great confusion has arisen among agricultural writers respecting the action of some manures. For example, much ingenious speculation has been indulged in to account for the well-known fact, that phosphates have, as a general rule, a more beneficial action on the turnip-crop than on any other. This, however, admits of a simple and consistent explanation, when we reflect that the size of the seed of the turnip is infinitely less in proportion to the space which the plant ultimately occupies, than is the case with any other plant.

The seeds of clover and grasses are small, but as they are thickly sown over the ground, the individual plants do not require to run far in search of phosphates; and they have also more time to search for a supply. With the turnip, it is different; it is sown at a season of the year when vegetation is stimulated by a high temperature. The small seed of the turnip has no phosphates within itself to produce a large growth of leaves and rootlets; and thus, unless it have a liberal supply added as manure, it cannot grow with vigour or rapidity. For this reason, phosphates must often be added to the soil to produce a crop of turnips, when these substances are by no means awanting, and not even deficient in quantity for growing other crops, which must absolutely obtain a supply as large, but whose facilities for obtaining it are much greater, so that they are less dependent on an artificial supply.

A similar rule holds in the application of phosphate to plants as in the application of ammonia. In the case of different plants requiring absolutely the same quantity for their growth, the effect of the application will

be less in proportion to the facilities which each plant has of obtaining it. Perennials are much less dependent on a supply of phosphoric acid than annuals, because, always filling the soil completely with their roots, they are immeasurably better provided, when the growing season arrives, for obtaining a supply than a small seed. We seldom manure our clovers and grasses with phosphates, because, having a net-work of roots through the soil, they can obtain what they require even although the supply may be scanty. When grasses are largely benefited by phosphoric manures, such as bones, it is a sure test of the soil being remarkably deficient in phosphates.

The practical application of these principles, however, will be further illustrated when we come to treat of manuring particular crops. The next theoretical division of our subject is one which has an intimate bearing on the physiology of plants, and also an important influence on the practices of agriculture.

THE METEOROLOGY OF AGRICULTURE.

The proportions of oxygen and nitrogen in the atmosphere are very uniform at all places on the earth, at all heights above its surface, and at all seasons of the year. Dry air contains about 77 parts of nitrogen, 23 of oxygen, and 1000th part of carbonic acid by weight. The atmosphere also contains minute quantities of ammoniacal vapour, which furnishes a supply of nitrogen to plants. Besides these, the vapour of water is always a component of the atmosphere, though it varies more in quantity than any of the others.

The higher the temperature of the air, the more moisture can it hold in an elastic state. The capacity of the air for holding moisture is about doubled for every increase of 20° of temperature on the scale of Fahrenheit. In saturated air, therefore, the proportions of moisture vary with the temperature. At 32°, air cannot contain more than 1-240th part of its weight of vapour; at 52°, 1-120th part; and at 72°, 1-62d part.

There are good grounds for believing that the amount of ammonia in the air is directly as the quantity of moisture it contains. The supply is larger in hot and moist weather, than in cold and dry. This supposition is so far supported by the fact, that all plants are less dependent on a supply of ammonia in the soil in the warm season, than in the cold: in other words, it takes more manure to grow a plant in spring than in summer.

In illustration of this principle, we have only to bear in mind that market-gardeners who force plants early in the season, require to dress their land with the richest manures. Phosphoric manures have no effect on turnips which are sown early in the season, though they are well known to have a very beneficial influence when applied to turnips sown in June. It is therefore certain that plants are less dependent on a supply of ammonia in the soil in summer than in spring. The vivifying influences of a high temperature, have no doubt much to do in giving plants greater vigour to abstract ammonia from the soil; but when all the facts are fully considered, they indicate that the leaves of plants have not only greater powers of absorbing ammonia directly from the atmosphere in warm than in cold weather, but that there is more for them to absorb. There is a numerous array of agricultural facts which appear to admit of no other explanation.

Without going into detail on this subject, we may merely remark, that phosphates have frequently a beneficial effect when applied to all the cereals, legumes, and root crops, when sown late in the season, but without effect when sown early. Their effects, however, are more marked according as the seeds are small, and the size of the full-grown plant is large. For this reason, turnips are more grateful for a supply of phosphates than any other plant which the farmer raises. But barley and oats, when sown in May, are frequently largely benefited by phosphates on the same soils where they would not be benefited by the same application if sown in March. The theoretical dictum which has been put forward by English writers, 'phosphates for turnips, and ammonia for corn,' has led to much misconception regarding the facts involved. If it be necessary to draw distinctions on this head with respect to the requirements of annual plants—always bearing in mind the qualifications we have made—it is pretty near the truth to say, '*ammonia for spring, and phosphates for summer*.'

Keeping in view the principles that have been so far illustrated, we shall, in approaching the more practical subjects, now touch upon the

PHYSICAL CONDITION OF SOILS.

This is one of the most important elements that determine the natural distribution of plants over the surface of the earth. To maintain plants in a healthy growing state, they must obtain a certain supply of moisture from the soil. Plants require different amounts of moisture from this source, as some evaporate a larger quantity of water from their leaves than others. The capacity which soils have of retaining the rains which fall, or of absorbing moisture from the atmosphere, has thus a great influence on their fertility.

In a state of nature, we find plants that require little moisture for their healthy growth, take possession of barren sands; while those that require a larger amount, fix upon soils which are more absorbent or retentive of moisture. The habits of plants, in regard to their necessity for moisture, and the physical conditions of soils, thus determine the character of the natural vegetation that covers the ground.

The agriculturist must often endeavour, however, to make all varieties of soil fitted for growing the particular crops that are most in demand. As his art advances, and his resources become more numerous, the mechanical condition of soils is more under his command, and he strives to give the different varieties such treatment as will fit them for growing all kinds of plants, irrespective of their physical characters.

Tillage, or other means of disintegrating and pulverising the soil, has the effect of rendering it more absorbent of moisture. It thus so far compensates for a larger fall of rain, and tends to maintain plants in a healthy growing state, without which they cannot work up the carbonic acid, ammonia, and other materials that they find in the soil and atmosphere. Tillage, however, is more particularly useful as a means of putting annual plants in possession of the soil, and of causing the organic matter which it contains to decay. Many perennial plants are not benefited by tillage, and most are independent of it. Thus, all our ameliorating crops, such as grasses and clovers, receive no cultivation, and produce as much vegetable matter as those that do.

This fact is rendered still more apparent by viewing what takes place in the forest, where the roots of the trees obtain a greater supply of moisture from the shade which the leaves afford. The shade of the forest is the natural substitute for the absorption of moisture that takes place in a well-tilled field. For instance, the natural habit of the vine is to have its roots fixed in the cool shade of the forest, where it grows without tillage or manure; but the cultivated plant, by being placed in conditions which are at variance with its natural habits, requires careful cultivation.

Forgetting the natural habits of the vine, Jethro Tull founded his theory of the nutrition of plants upon the beneficial effects which tillage had upon its growth. According to him, the food of plants was 'earth,' and 'earth' alone, which only required to be sufficiently divided by cultivation, to allow it to pass into their vessels. In the case of the vine, however, the good

effects of tillage are owing to its rendering the soil more absorbent of moisture, and affording some compensation for the shade which its roots obtain when growing in its natural state. Jethro Tull might have perceived, as clearly as Adam Smith did, that 'a field overgrown with briers and brambles may frequently produce as great a quantity of vegetables as the best cultivated vineyard or cornfield.'

Agriculturists classify the particular physical conditions of soils under the following general heads: sandy, gravelly, clayey, chalky, alluvial, and loamy.

Sandy soils, containing a large percentage of silicious matter, are often unfruitful, owing to the shallow-rooted plants being readily scorched during warm weather. Many of our sand-downs in the vicinity of the sea are of this character, and hence they are more profitable when allowed to remain covered by the grasses which are natural to them. These soils cannot absorb much moisture from the air, nor retain what falls as rain. Sandy soils are most productive in moist seasons or in moist climates. Sir Humphry Davy found that the coarsest and most barren soils, when dried at 212°, absorbed least moisture in a given time. The lowest in the scale of absorbing capabilities was a soil from Bagshot Heath, 1000 grains of which only gained three grains in an hour, exposed to air at the temperature of 62°, saturated with moisture.

Gravelly soils derive their name from resting on gravel. They are usually sandy in their character, and contain pebbles and boulders; but being liable to be scorched by draughts, their produce is variable.

Sandy loams contain a larger proportion of vegetable matter than the above, and thus being more absorbent of moisture, are better fitted for maintaining plants in healthy conditions. Sandy loams are benefited more than any other class by tillage, which increases their absorbing powers. These qualities fit them especially for turnip-husbandry. So also in America, the sandy loams are well suited for maize and its culture in summer. Deep cultivation, more especially in dry climates, is a most important means of increasing the retentive and absorbent qualities of light soils. The benefits of cultivation are apparent from the fact, that grasses on sandy loams are liable to be scorched by the droughts of summer to a greater degree than the turnips in a well-tilled field.

Clayey soils, if they contain little vegetable matter, are the most difficult class to cultivate. Unless they are managed so as to allow the frost of winter to assist in their pulverisation, it is often a most difficult matter to effect this by all the implements at the command of the farmer. Drainage, however, has done a great deal towards rendering this class more easily cultivated; and at present, they are made to produce excellent green crops in ordinary years. Clover and artificial grasses produce heavy crops of hay on clay soils, but the pasture is generally inferior, as the treading of stock seems to be adverse to the healthy growth of grasses on these soils.

Chalky soils have a large proportion of calcareous matter in their composition. The valleys of the chalk districts in England, however, usually abound in clay, and the soil is particularly tenacious. The chalk-loams are well suited for the growth of all kinds of crops, more especially of wheat, barley, clover, and turnips. These are the only soils upon which saintfoin and lucerne thrive.

Alluvial soils are composed of the finest particles of earth which have been washed by floods from the upper part of the courses of rivers. They have generally a rich level surface, and being deep, yield excellent crops of wheat, oats, barley, beans, potatoes, and clover. To manage these lands well, the farmer must undergo a thorough training, so as to enable him to cultivate them with the least expenditure of labour, consistent with giving to the crops those conditions fitted for promoting their vigorous growth. A celebrated soil from Ormiston, in East Lothian, which contained more than half its weight of finely divided matter, absorbed, in Sir Humphry Davy's experiments, six times more water than the soil from Bagshot Heath.

Loamy soils are of great variety, for the term *loam* is one of the most indefinite in agricultural language. Loam may be generally described as a mixture of sand, clay, and vegetable mould, moderately cohesive, less tenacious than clay, and more so than sand. These qualities render them suited for all kinds of crops, which are raised with greater certainty than upon any others.

Varieties of soils, however, are as numerous as the rocks from which they have been formed. The adaptation of the different varieties of soil for the growth of particular crops, will be best illustrated when we come to consider the culture of the particular crops. In the meantime, we shall notice what may be called

THE CHEMICAL CONDITION OF SOILS.

In nature, we find the earth covered by a vegetation that thrives upon the same spots for ages. But it is well known, that if some of our cultivated crops are frequently repeated on the same soils, they become a prey to different kinds of diseases. In nature, those plants which are fitted to the chemical condition of the soil, take possession of it; but man endeavours to make certain plants grow upon every variety of soil.

It is well known that saintfoin and lucerne will not thrive upon land, unless it contains a large quantity of calcareous matter. Now, the analysis of the ashes of these plants does not indicate that either of them requires more lime for building up its vegetable structure, than some others that thrive upon soils containing but a small quantity of calcareous matter. Turnips, it is well known, are subject to finger-and-toe, a disease for which a liberal application of lime to the soil will act as a preventive. That the lime in this case, however, does not act by merely affording lime as a constituent to the crop, is evident from the fact, that it does not cure finger-and-toe when applied, like other manures, at the time the crop is sown. It must be applied for a year or two previous, that it may have time to produce a certain chemical effect upon the land. The particular action in this case, we have been led to believe, consists in the lime directing or controlling the particular decomposition that all vegetable matter is undergoing in the soil. The particular products that an unlimed soil often yields, interfere with the healthy action of the absorbing powers of the roots of plants, which are thereby prevented from taking up a due supply of the earthy matters. The deficiency of these matters induces a corrupt state of the vegetable juices, which thus become the *nidus* for particular kinds of insects. It has always appeared to us that the insects are not the cause of the disease of finger-and-toe or anbury, as Professor Buckman supposes, but a consequence of diseased conditions.

Vegetable physiologists who suppose that plants absorb their food mechanically along with water, are evidently at fault. The process is apparently a chemical one, similar to that which takes place when leaves absorb carbonic acid and ammonia from the atmosphere. But, more than this, we have long been led to the conclusion, before being aware of Gazzeri's experiments, that roots virtually exercise, by their contact with solid matter, an incontestable action in imparting solubility to it. The recent experiments of Professor Way, when rightly considered, seem to render this view more probable. They indicate that the rains have little power to wash out of the soil certain constituents that form the food of plants; unless the roots, therefore, had the power of imparting solubility, these substances could not find their way into the structure of plants in sufficient quantity for promoting rapid growth.

In order that the roots of plants may exercise on the substances constituting their food an absorbent action, which is equivalent to a power of selection, they must be placed in a medium capable of maintaining their healthy functions. That special conditions are necessary to the growth of some plants, is patent to all in the case of the particular kinds which grow in fresh and in stagnant water, in soils abounding in acids, and in others abounding in alkaline earths.

This peculiar chemical condition of soils, which is a quality over and above the mere presence of the constituents of plants, is a highly important one. Finger-and-toe in turnips, clover-sickness, the dying out of certain grasses in particular soils, and many phenomena in the vegetable world, arrange themselves for elucidation under this head.

The particular quality of soils also, which practical men distinguish by the terms 'sharp' and 'deaf,' arises from their chemical condition. It ought to be borne in mind that the repetition of a particular crop on any soil does not necessarily unfit the soil for producing it in a healthy state, if the chemical conditions are favourable. In many soils deficient in calcareous matter, the quantity of crude vegetable matter which turnips leave by their decaying roots, impairs the healthy functions of their roots when too frequently repeated. Lime cures this quality of the land, by correcting or neutralising the decomposing matters left in the soil. One of the most interesting facts elicited by Mr Lawes in his experiments at Rothamsted is, that he has raised turnips on the same land with superphosphate of lime for eight or ten years in succession. The American farmers also sow clover every other year, but do not complain of clover-sickness. Clover-sickness and finger-and-toe, however, sometimes arise from an actual deficiency in the soil of the substances found in the ashes of the plants. Without going into the practical illustration by which we have been guided on this question, we have said enough to shew the importance of the chemical conditions of soils, in explaining some of the facts of agriculture.

CLIMATE OF GREAT BRITAIN.

Our space being necessarily limited, the effects of climate on crops and systems of farming will be best treated when considering the culture of particular crops, and the practical economy of rotations. Under the present head, we shall confine ourselves to some general remarks on temperature, rains, and evaporation.

However useful the *means* of monthly temperature may be for some purposes, they are of little use for illustrating the effects of climate on crops. It is obvious that the *mean* daily temperatures give a very inadequate idea of the character of the weather of any day. The mean may be made up by a wide range of temperature, or the reverse. Thus, a mean of 60° may be made up of a maximum of 75° and minimum of 45°, or a maximum of 65° and a minimum of 55°. Such atmospheric conditions, however, would be attended with different effects on the soil and plants. Did our space permit, we would shew that the mean maxima and mean minima temperatures put us in possession of data to estimate the effects and intensity of many climatological influences. The following are the mean maxima and mean minima temperatures in the different months at a few stations:

Temperature.

	January.		February.		March.		April.		May.		June.		July.		August.		Septem.		October.		Novem.		Decem.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Chiswick (Middlsx.),	41·1	30·9	45·9	33·6	50·8	35·4	57·1	37·7	66·0	43·5	71·7	49·9	74·1	51·9	73·6	51·7	67·0	47·1	59·1	42·0	50·4	36·9	15·4	34·9
Thwaite (Suffolk),	38·8	31·5	44·2	33·7	48·6	36·2	54·6	39·5	62·9	45·5	69·1	51·8	71·9	54·5	70·6	52·6	64·7	49·7	58·2	45·5	47·6	38·2	43·1	36·0
Helston (Cornwall),	48·3	40·4	48·6	38·3	50·7	39·9	54·6	43·9	60·6	47·9	67·5	51·4	68·9	54·9	68·3	53·8	66·3	52·5	58·5	47·2	53·3	43·8	48·7	40·4
Highfield House Obs. (Nottingham), .	40·6	33·5	48·1	36·8	49·4	37·0	53·7	38·2	68·8	47·0	73·3	53·7	75·9	56·1	71·6	53·9	65·4	49·3	57·1	43·9	49·3	39·7	42·8	34·9
Edinburgh (Mid-L.),	40·0	34·0	42·5	35·5	45·0	39·0	51·5	40·5	59·7	45·5	64·7	49·3	68·5	53·5	65·0	50·0	61·5	48·5	54·0	44·0	46·5	39·5	44·0	37·0
Rothesay (Bute), .	41·4	35·4	43·1	36·3	46·1	37·0	51·3	40·3	59·6	45·6	63·5	50·5	65·2	53·2	64·2	51·2	59·0	48·0	53·3	44·9	46·6	39·6	43·8	37·8
Dunino (Fife), .	38·8	32·2	40·3	33·4	45·3	33·3	50·8	35·7	58·0	42·3	64·7	47·8	66·6	50·5	64·9	49·0	59·9	46·6	51·2	40·1	44·6	36·4	40·4	33·1

The quantity of rain which falls in different districts, is another important point. The table below gives the number of rainy days and amount of rain in inches at the following stations:

Rain.

	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.	No. of Rainy Days.	Inches Rain.
	January.		February.		March.		April.		May.		June.		July.		August.		Septem.		October.		Novem.		Decem.	
Chiswick (Middlsx.),	14	1·56	16	1·45	13	1·36	14	1·55	16	1·67	12	1·98	16	2·44	16	2·37	12	2·97	16	2·46	15	2·58	18	1·65
Thwaite (Suffolk),	13	1·77	16	1·85	8	1·76	8	1·77	11	1·37	10	2·71	15	1·65	13	2·39	12	2·7	18	2·29	18	1·95	12	1·59
Helston (Cornwall),	20	4·27	13	3·2	11	2·04	12	2·9	8	1·8	9	2·2	11	2·3	10	2·93	8	3·1	18	2·9	15	5·2	20	4·4
Stroud (Gloucester),	13	2·77	13	2·4	11	2·5	18	2·7	13	2·27	13	2·4	15	2·9	12	2·49	13	2·8	16	2·9	14	3·29	13	2·6
Edinburgh (Mid-L.),	13	2·12	14	2·0	11	1·75	12	1·8	12	2·6	10	2·6	14	3·0	11	2·7	12	2·2	13	2·4	13	2·75	12	2·4
Dunino (Fife), .	11	2·02	11	2·4	10	1·52	10	2·07	10	2·3	12	3·1	14	3·55	12	2·5	9	2·05	15	3·6	14	3·7	11	1·6
Rothesay (Bute), .	—	2·87	—	3·0	—	3·46	—	1·97	—	1·78	—	2·03	—	3·0	—	3·4	—	3·77	—	4·3	—	4·50	—	4·43

More rain falls on the west coast than the east; but it is worthy of observation that the excess is principally confined to winter and autumn. In the eastern counties of England, most rain falls during the warm months, but the evaporation being great, the climate is then dry.

From these tables, the distinguishing peculiarities of climate in different parts of the British Islands are apparent. The warmer nights and cooler days of Cornwall give as high a *mean* as the cooler nights and warmer days in Middlesex. Even when the fall of rain is the same at two places, the effects of this different composition are very marked upon crops, inasmuch as the range of temperature determines to a considerable extent the force of evaporation.

The drying or evaporating power of the atmosphere is also an important matter to be attended to. The range of the thermometer is less on mountains than in valleys, and, consequently, corn is always more difficult to harvest on high grounds, owing to the diminished force of evaporation. (See METEOROLOGY.)

CULTIVATION.

One of the principal objects of cultivation is to uproot and destroy all plants but those that the farmer desires to rear. No implement has been found to effect this so well, and at the same time so economically, as the plough, which Mr Mechi has facetiously termed 'an undertaker and grave-digger.' It ought to be borne in mind that it is of quite as much importance to have the grasses in a field of pasture completely buried, as to have the land thoroughly pulverised. The pulverising of the land, though it has the effect of rendering it more absorbent of moisture, is chiefly useful for the purpose of allowing plants readily to take possession of it. In this matter, the same principles in a measure apply as in manuring. The smaller the seeds of vegetables, the quicker their growth, and the larger the full-grown plants; so much the more careful and perfect must the preparation of the ground be. Thus, it is well known that the turnip requires a better tilth than other crops.

The plough no doubt at first sight appears a very simple implement; nevertheless, upon no one has there been so much mechanical skill expended, in rendering it adapted to different varieties of soil. In ploughing, an important principle must be steadily kept in view—that clay or tenacious soils should never be ploughed when either too wet or too dry. In ploughing the first time for fallow or green crops, it is of importance to begin immediately after harvest, or as soon after wheat-sowing as possible, in order that strong tenacious soils may have the full benefit of the frost. On wet stiff soils, frost acts as a most powerful agent in pulverising the earth: it expands the moisture, which, requiring more space, puts the particles of earth out of their place, and renders the soil loose and friable. On such soils there is no rule of husbandry more essential than to open them as early as possible before the winter frosts set in. If left till spring, clay-soils may be too wet for ploughing; or if the season be dry, the earth, when turned up, will be in hard clods, very unfit for vegetation. Therefore, on farms having a proportion of clay and of light soils, it is necessary that the strong wet land should be ploughed first, provided the weather will allow.

Ploughs.*

From the time when animal power was first applied to the cultivation of the soil, an implement of various form has been used for the purposes of a plough. In primitive times, it usually consisted of a piece of bent wood, attached to which was a broad share, either hardened in the fire, or faced with iron, a single handle, and no mould-board, or rest; and in those regions where the burning sun destroys the surface-matting of turf, such a simple instrument may still be used. But the requirements of modern agriculture have called forth an implement of greater power and perfection of form. A hundred years have not elapsed since the only plough in use in Scotland was rude, cumbrous, unwieldy, and usually drawn by eight oxen. When horses were attached to it, a lighter form was required; and after rural improvements began to spread, James Small, a Scotch plough-wright, had the merit, of changing its form, and adapting it to the wants of the time. He duly proportioned the several parts, and fitted the coulter and share to cut, and the mould-board to raise and turn, a rectangular-shaped furrow, at a much less expenditure of force, and with greater precision than had ever been done before. For many years, this was almost the only plough used in Scotland. Wilkie of Uddingston, having formed all the parts of the implement of iron, made some alterations

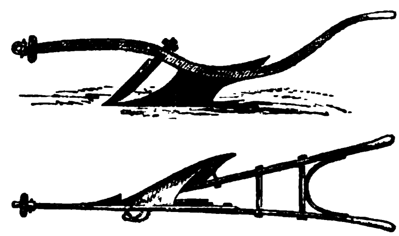


Fig. 1.—Swing-plough.

upon the set of the coulter and share, and also on the form of the mould-board, so that on thin clay-soils narrower furrows might be produced, with a greater shoulder or apex than the rather plain flat work which characterised Small's plough. With various slight alterations by different makers, until thorough-draining changed the texture of the soil, there was little improvement effected upon this implement. But since then, various alterations have been made both in England and Scotland. Ponton in West Lothian, and Sellars, Huntly, are the most recent improvers of the swing-plough. The first-named maker constructs his with long convex mould-boards, and irons set to cut high; Sellars, again, has the long mould, but his are plain cutting ploughs. Mr Finlayson, Bridge of Allan, has recently attached a couple of wheels to the common plough, by which all the regularity and equality of

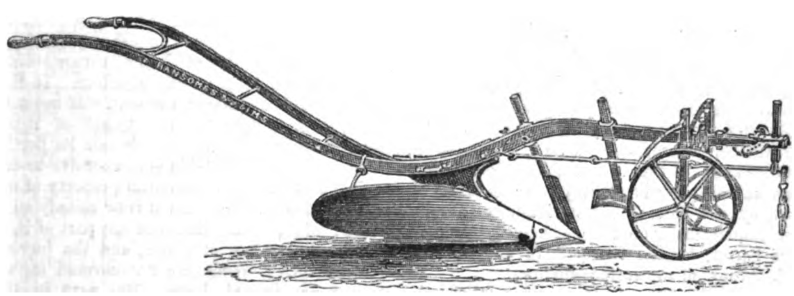


Fig. 2.—Ransomes' Wheel-plough.

the English wheel-ploughs are attained; the wheels can be detached, and the implement again used as a swing-plough. In England, wheels had been in use from a remote period; and there the spirit of improvement took advantage of these to construct an implement capable of making excellent work, with the assistance of little skill in the workman. In Scotland, most of the improvements implied the existence of great skill in the ploughman; and the result has been that in such hands the Scotch swing-plough is able to produce any description of work, while that of the English wheel-plough is always the same. Ransomes of Ipswich has

* For the following remarks upon ploughs, grubbers, and harrows, we are indebted to Mr Melvin, Bonnington, Ratho, who has devoted much attention to the principles upon which they are constructed; the portion on agriculture generally, is by Mr R. Russell of Kilwhiss, Fife; and the remaining section on spade husbandry and the culture of waste lands, has been prepared by Mr J. Clarke of Long Sutton, Lincolnshire.

the merit of originating several improvements on the wheel-plough, and his latest form is represented, fig. 2. During the last ten years, not a few makers have been keenly contesting for the merit of constructing the implement that produces the finest work at the least cost of power. Mr Howard has been tolerably successful: his plough somewhat resembles the above; and Mr Busby of Bedale, with the assistance of Mr Oathwaite, contrived very beautiful mould-boards, which were held first at the Exhibition in 1851. For several soils we prefer his plough to others; although Mr Ransomes, with his last improvement, has again taken the lead. None of these very beautiful implements please the Scotch farmer in ploughing lea, as they turn the furrow rather flat over; but they unite in a high degree those contrivances which go far to make up for the guiding-hand of man. They have long finely shaped mould-boards, rather short broad shares, straight coulters, and with the two wheels on level land, can almost move unattended. It is difficult to lay off land into ridges with them, and drilling cannot be done, neither do they answer for the mode of ploughing which is called *gathering* in Scotland, as the space which is left when the last furrows are taken out, is very broad; and they don't make the neat close finish that the swing-plough, when well handled, does. It may almost be said that, with the wheel-plough, it is the plough that does the work; with the swing, it is the man. It is not necessary here to enter upon any full examination of the principles upon which the various ploughs are constructed. In Scotland, they may be divided into two classes—the first follow Small's model, and are what are called plain cutting implements; the other, Wilkie's, which are capable of both plain and high-shouldered work. In England, all the ploughs we have seen, cut plain—that is, raise and lay the furrow at an angle of about 45°. After the land became drained, considerable difficulty was felt with the concave moulds, from their not throwing the soil cleanly off; and to amend this, a longer and more convex form was adopted. These are now coming into general use.

Trench Ploughs are either worked with three or four horses, and are constructed on the same principle as the plain cutting common ploughs, but with all the parts larger and stronger. The ploughs constructed by the Marquis of Tweeddale for this purpose, unite to a certain extent the properties of the subsoil and trench plough. Although they have been before the public eight or ten years, and have succeeded well at Yester, as yet their adoption has not become general. (See figs. 25, 26.)

The Subsoil Plough is now less heard of than it once was. Although the theoretical principle on which the operation of subsoiling is founded, is undoubtedly correct, and although the implement, as improved, effects the breaking up of the subsoil thoroughly, yet the effects visible from its use are frequently not so great as to induce those who most hopefully commenced with it, to continue further operations. Read's, as improved by Slight, Edinburgh, is the steadiest and best implement. Some subsoil-ploughs of very light construction can be drawn by two horses; but in ordinary subsoils, the stronger implement cannot be effectually wrought without four horses, besides the pair in the common plough which throws off the surface-furrow.

Hitherto, the application of *steam-power* to ploughing has been more in the way of experiment than of useful work. Where stationary engines have been used, a great loss is sustained in transmitting the power to a distance; and where locomotive power has been applied, a like loss has to be met in overcoming the resistance of the soft yielding surface-soil. Although high authorities are of a contrary opinion, it appears to be impossible to apply locomotive-power without resorting to a more solid surface than that of the soil, and unless part of the weight of the engine be supported on the firm subsoil, it is not easy to see where this support can be had. Resting on the surface-soil, the slightest shower so clogs the machine that it comes to a stand. This cause alone, in an uncertain climate, would operate greatly against its usefulness, even though it could be profitably wrought.

Ploughing.

The usual dimensions of the furrow-slice in lea or in hay stubble, are eight or nine inches in breadth, by six in depth. In stubble for green crop, the breadth may be ten inches, by seven or eight in depth; and the force of traction amounts to between three and a half and four and a half hundredweights. The extent of land ploughed per day, by a man and pair of horses, depends on the soil, and the breadth and depth of the furrow. During the winter months, three-fourths of an imperial acre is the average amount gone over; but with the lengthening day, or in cross-ploughing, more can be done. There are three modes in which land is chiefly ploughed; the first, and once most common, is called

Gathering.—The usual breadth of a ridge being taken as eighteen feet, the ploughman sets up a line of poles along the middle of the first ridge. The poles are made nine feet long, for the purpose of measuring the distance from the edge of the field, at which they are to be set up. Along the line so formed, he drives his plough, throwing out a furrow; and after reaching the further headland, turns his horses to the left, and throws out another in the same line. He then returns back both of these furrows so thrown out, along with a portion of firm soil; and he may go on adding furrow to furrow on either side of the first two, until the space is gone over. In practice, it is found more correct to leave the outer half of the first ridge unploughed, and to plough the second half of the first ridge and the first of the next. In doing this, the ploughman is said to wind out the space, which means turning his horses always to the left.

Cleaving just reverses the positions of the furrows previously gathered. The ploughman begins where he formerly finished, and winds out each ridge by itself.

Casting is now by far the most common method of ploughing land. The ploughman proceeds to set up poles eighteen feet from the side of the field. Along this line he throws out two furrows right and left, returns them again, and ploughs round these until thirty-six feet have been gone over; forming thus two ridges. He then measures a space of fifty-four feet from the last-drawn furrow, or seventy-two feet from his first-drawn line; again sets up his poles, ploughing other thirty-six feet there, and leaving a space of thirty-six feet between the two first-ploughed pairs. This space, forming two ridges, he now proceeds to wind out, turning always to the left, instead of to the right as before. In this way, any breadth of land may be wrought. It must be borne in mind, that the longer the length of ridge, and the fewer turnings, the more work can be performed; and that angular-shaped fields are expensive to cultivate.

The first and most essential property of every plough is, that it shall throw the furrow cleanly off the mould-board; when earth adheres to any part of it, the friction thereby causes loss of power, and the furrow is imperfectly turned; weeds are not covered in, and the old surface not turned down. The next is, that it shall leave the furrow in that position that exposes the greatest amount of soil to the action of the air; and also, that the furrow so turned over, while preserving that shape, shall be so rent internally by the action of the irons in cutting and raising it, that the air and frost may be enabled most easily to penetrate its substance. If, then, we are right in this position, either very long or very short mould-boards are objectionable: the last from breaking up too much the shape; and the other from polishing off too smoothly the exposed surface. The action of the plough on the soil is not so effectual as that

of the spade, from the spitfuls being all separately cut. But the amount of surface which a well-turned furrow presents to the air, is much greater than what any digging can throw up; and hence the advantage of having the furrows continually broken by frequent rents, and these openings not plastered up by a long mould-board, as is done in some of the more recent forms of plough, which compress and smooth the furrow after it has been fairly put in its place.

In the construction of ploughs, strength must never be sacrificed to lightness; a stone or two more weight is often of use in heavy soils; and the beam, head, and stilts must be thoroughly stiff and unyielding, when under the pressure of the horses and man, in the soil. A well-constructed plough should never be touched by the ploughman, either with the screw-driver or hammer. The share and coulter are the only parts he has control over.

A form of plough, known as the *turn-wrest*, is much used in Kent, and is highly thought of by the farmers there, as admirably adapted for clearing the land from grass, &c., as well as for loosening the soil. It is capable of being used for a variety of purposes. A view of it as improved by Mr Smart of Rainham, and manufactured by Ransomes and Sims of Ipswich, is given in fig. 3. The turn-wrest plough lays the furrows all in

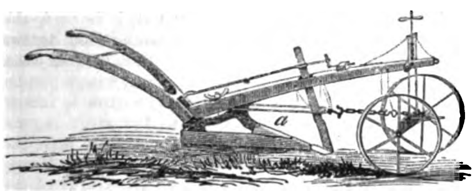


Fig. 3.—Smart's Turn-wrest Plough.

one direction from one side of the field to the other; this being effected by the wrest *a*, which acts as the mould-board of the ordinary plough, and by a very simple mechanism can be changed from one side of the plough to the other—'so that either becomes alternately the mould-board as the furrow requires to be turned.'

Grubbers

are now much more in use than formerly, the soil being more open and easily penetrated by their teeth. It is often far more advantageous simply to loosen up the soil than turn it over. Especially since green crops have been extensively grown on clays, this implement is almost essential, as thereby the disadvantages of a spring-furrow are dispensed with. The upper portion of the soil, loosened and ameliorated by the winter's frost, not being turned down, still allows the drill-plough to form an open, friable ridgelet for the seed. In the cleaning of land, this implement is also most advantageous; and we know of nothing better for this purpose than an improved Scoular or Kirkwood grubber, with two wheels about two and a half feet in diameter, and the teeth proportionally long. They not only work the land most effectually, but never clog, as those with wheels of smaller diameter do; and when tested along with the one-wheeled Tennant's or Scoular's, are infinitely superior. On sloping land, when crossing the slope, a one-wheeled instrument works very imperfectly. Much of the bad odour into which grubbing has fallen in some places, has arisen from the use of imperfect implements, or from the want of properly trimming them; but it must always be borne in mind that surface-weeds are not removed by grubbing. Where these abound, and are troublesome, there is nothing like the plough for destroying them. The quantity of land which a two-horse implement will go over in a day, is generally four times the quantity which the same team could plough. In Scotland, the grubbers chiefly in use are Tennant's and Scoular's one-wheeled ones, and Scoular's and Kirkwood's three-wheeled implements. In England, there are, under the name of Cultivator, Coleman's and Johnston's, Bentall's Broadshare, Ducie's Drag, &c., all of which are more complicated and heavy, with more cast iron in their construction than those in Scotland; but they work well when sufficient horse-power is applied to them.

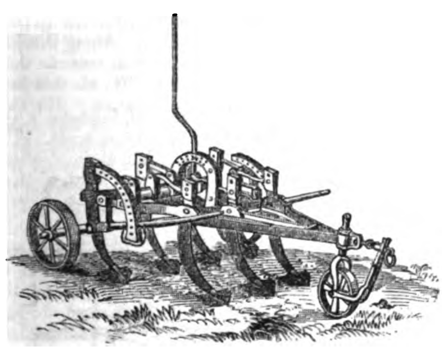


Fig. 4.—Coleman's Cultivator.

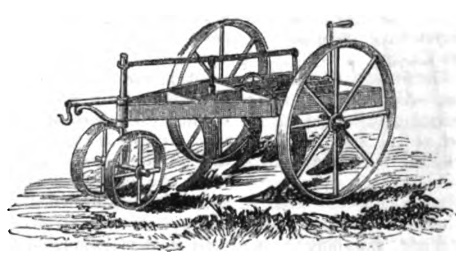


Fig. 5.—Ducie Drag.

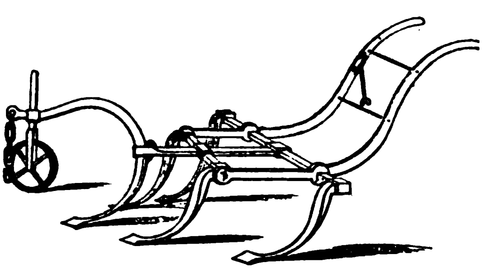


Fig. 6.—Tennant's Grubber.

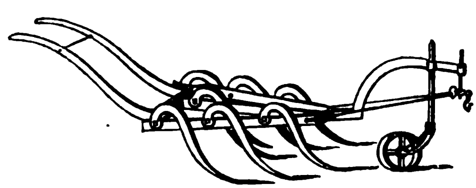


Fig. 7.—Scoular's Grubber.

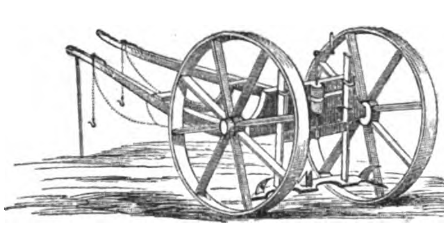


Fig. 8.—Johnston's Skim Cultivator.

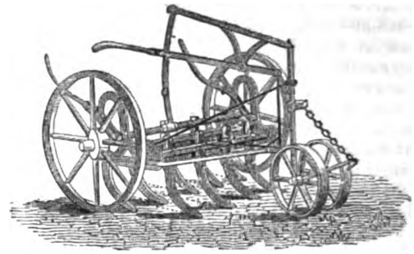


Fig. 9.—Biddell's Scarifier.

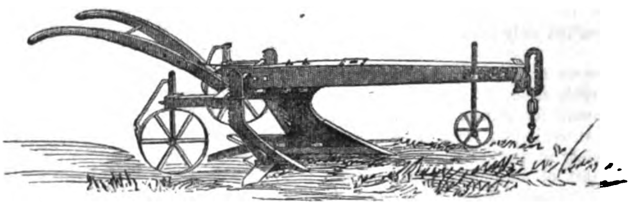


Fig. 10.—Bentall's Broadshare.

We believe that more attention to the action in the soil of this implement would result in the construction of still greater improvements than have hitherto been effected. It has never been determined what form of tooth is best—some advocating a diamond-shaped point; others, a broad chisel; and others, a duck-foot shape. We prefer, after many trials, a broad chisel point, four inches at least, which, with the bend upwards, works the soil very effectually, but requires considerable force.

Harrows.

The early form of harrow was that of a board of wood with wooden pins fixed in it. Iron then took the place of wood for these teeth; and at length it was found that a framework of wood, consisting of *slots* and *bulls*—to use the language of the joiner—into which iron tines were driven, made a more effective implement. These harrows were generally made of a square form, and one was allotted to each horse. By making these of a rhomboidal shape, and coupling two together, and attaching a long tree to them, as in fig. 11, the irregular action on the soil of the former kinds was avoided, and each tooth operated on a separate portion of soil and at an equal distance from the one next it, as shewn in the dotted lines.

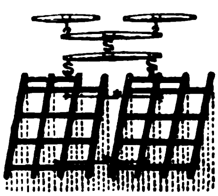


Fig. 11.

These harrows have for long been made entirely of iron, and are very effective on several sorts of land; but not so on all, as there is too great rigidity about them, and they do not adapt themselves to any slight irregularity of surface, so that a more pliant implement was required. This, to a certain extent, was found in the Bedford harrow, originally constructed in three divisions, and containing seventy-two teeth, being thirty-two more than in the common harrow. The first formation of these Bedford harrows has been changed by introducing joints into the separate connections, and thus a far more pliant, though necessarily weaker implement has been produced, as shewn in fig. 12. These harrows work admirably in the same line as the furrow; but in crossing they are apt to pull back the closing furrows of the ridges; and on newly ploughed or stiff lea-ground they are objectionable on this account. They are heavier to draw than the common kind, and do not shake out the quicken roots or couch-grass very freely when the land is being cleaned: on this account, it is preferable always to have both sorts on the farm. The Bedford harrow costs about £1 more than the rhomboidal. Other

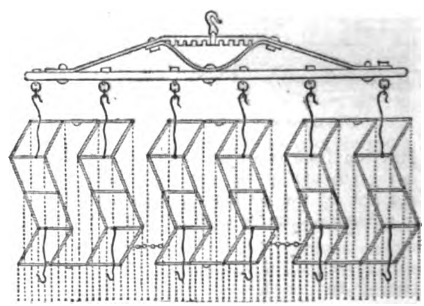


Fig. 12.—Howard's Harrow.

forms have been introduced. Smith of Deanston's web-harrow was well fitted for covering grass-seeds. That form represented in fig. 13, is another attempt at progress, for in the implements hitherto described, whatever amount of motion may exist between the separate

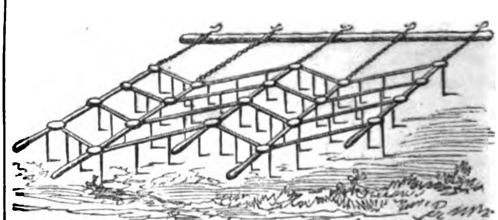


Fig. 13.—Coleman's Diagonal.

harrows, the distance between the teeth remains the same. But in that figure an attempt is made to have the space between the teeth altered at will, so that coarse or fine work may be made. All harrows are now made to cover a space of nine feet, and are drawn by one pair of horses. In ten hours, about sixteen imperial acres can be gone once over. As it is often necessary to go from four to seven times over the same ground before the surface can be made sufficiently fine, it would seem advisable to have an implement, covering a narrower

space, but more effective, so as to save several of these repeated journeys.

There is a useful article called a *drill-harrow*, for cleaning and lowering down bean and potato drills. This implement consists of two parts, each of which fits over the top of the drill, and, being concave on the under surface, acts on the top and sides. It is drawn by one horse, and is very effective.

Other sorts of harrows there are for the purpose of cleaning the intervals between the rows of green crop; but these are now less used, the horse-hoe being made to do much of the work to which they were applied.

The Norwegian harrow is an implement which is much used in some localities; and as it can be wrought in showery weather, when it is impossible to have rollers going, it has advantages which commend its use. It acts more in the way of cutting than compressing, and is also preferred on this account.

The roller and *clod-crusher* are implements that cannot be dispensed with on any farm. The smooth iron roller is too well known to require any description;

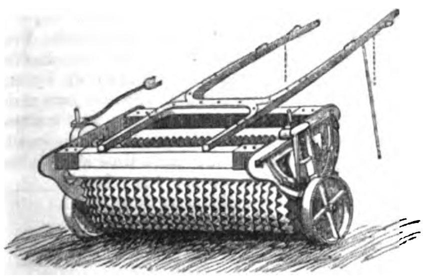


Fig. 14.—Crosskill's Clod-crusher.

and Crosskill's clod-crusher is now generally acknowledged to be a very efficient implement for strong clay lands.

Carts.—Two kinds of machines are in use for conveying produce to market and other purposes in husbandry—wagons and carts—and of these there are several varieties. Wagons with four wheels, and drawn by two or more horses, are acknowledged to be best adapted for conveying great loads to a great distance, and that is their principal merit. For all ordinary purposes connected with husbandry, the one-horse cart with two wheels is preferable.

The Scotch cart, as it is called, is a most convenient and useful machine; and to add to its uses, it may be rendered serviceable for carting hay or straw by placing a movable frame on its sides, as represented here. The Scotch cart (without the frame) is suited for conveying any kind of material—dung, turnips, grain in sacks, &c.—and usually carries from eighteen to twenty-two hundredweights, when drawn by only one horse; with a horse in trace, the weight may be augmented. In Scotland, all grain for market is carried in these one-horse carts, and to any distance. On such occasions, one driver can take charge of two carts.

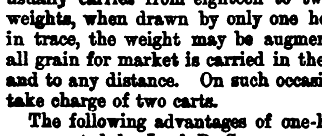


Fig. 15.

The following advantages of one-horse carts are well enumerated by Lord R. Seymour. 'A horse, when he acts singly, will do half as much more work as when he acts in conjunction with another; that is to say, that two horses will, separately, do as much work as three conjunctively: this arises, in the first place, from the single horse being so near the load he draws; and in the next place, from the point or line of draught being so much below his breast, it being usual to make the wheels of single-horse carts low. A horse harnessed singly has nothing but his load to contend with; whereas, when he draws in conjunction with another, he is generally embarrassed by some difference of rate, the horse behind or before him moving quicker or slower than himself; he is likewise frequently inconvenienced by the greater or less height of his neighbour: these considerations give a decided advantage to the single-horse cart. The very great ease with which a low cart is filled may be added; as a man may load it, with the help of a long-handled shovel or fork, by means of his hands only; whereas, in order to fill a higher cart, not only the man's back, but his arms and whole person, must be exerted.' To these just observations it need only be added, that in many parts of England there is a wasteful expenditure in horse-power, a couple of horses being often set to draw a clumsy wagon to market, containing a load which could with the greatest ease be drawn by one horse in a less ponderous machine.

Every well-conducted farm establishment is now, or ought to be, provided with a variety of small but useful machines—for slicing turnips or potatoes, chopping hay or pease straw, bruising beans, pease, or oats, weighing-machine, &c.—all which, of the newest construction, are to be seen at the establishments of agricultural implement-makers. Utensils for cooking food for cattle, dairy utensils, and tools for manual labour, need not here be particularised.

SOWING.

In Scotland, the greater part of the cereals are sown broadcast. In England, on the other hand, they are frequently sown by drilling-machines; indeed, in the eastern counties, they are almost all sown by machinery. Experience has hitherto seemed to shew that the benefits of drilling are more marked in poor soils than in rich, on light than heavy land, in dry climates than in moist.

At the same time, it was not to be expected that drilling by machines should be so much followed in Scotland, owing to the hilly and irregular nature of its surface. It gained a footing, however, pretty early in East Lothian, and we believe that the practice is still slowly extending.

Drilling is less advantageous in the case of late-sown spring crops, which grow up more rapidly, and keep down weeds. Up to a comparatively recent period, late sowing of cereals was very common in Scotland, and experiments on the drilling of these crops were not generally favourable. It is attended with greater benefits in early-sown spring crops, such as wheat and chevalier barley. On light and inferior soils, it is almost essential to the raising of these crops with any degree of certainty. This also applies to autumn-sown wheat on such soils.

The drilling of cereals effects a saving of seed, for if they are sown broadcast, more grain must be used, to prevent weeds springing up. In drilling, also, the seeds are deposited at an equal depth, and fewer of them are destroyed. When drilling has been adopted in Scotland, it has no doubt been customary to sow too much seed, a practice that should be avoided, as the crowding of the plants in rows stunts their growth, and renders the crops less productive. But the effects of using too little seed must likewise be guarded against, as this prolongs the life of the plants, causing them to tiller and produce more vascular stems, which are longer in ripening, and the quality of grain is inferior. Late-sown spring crops, therefore, should have a more liberal quantity of seed than early. On land in good condition, it is safer to sow two bushels of barley to the acre in the early part of March, than three by the middle of May.

It is also of importance to keep in mind that the land requires to be more carefully prepared in spring,

when the grain is drilled. The roots of the plants being nearer to the surface, are more liable to be influenced by the drought, unless the comminution of the soil is carefully accomplished

There are various kinds of machines for sowing grain. The English implement-makers have brought them to far more perfection than the Scotch. In the English machines, the seed is lifted from the box by cups attached to a barrel driven from the axle of the large wheels. The cups, emptying themselves into small hoppers communicating with the coulters by tubes, seem to be best adapted for effecting a regular flow of seed. The coulters, also, which form a bed for the seed, being jointed, move up and down, and permit of a uniform pressure, and, consequently, of an equality of depth at which the seed is deposited. This important principle of jointed coulters has only been recently introduced into the Scotch drills. The following sketch represents one of Garrett's corn-drills, which are in general use in the eastern counties of England.

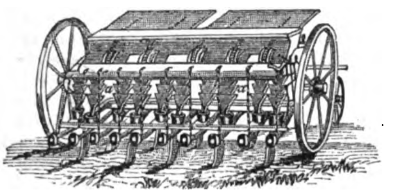


Fig. 16.—Garrett's Corn-drill.

One of the most important advantages of drilling cereals is the facility which it affords for keeping the crops free from annual weeds. In fact, the farmer has a much greater command over his crop when it is drilled than when it is sown broadcast. Weeds can be much more cheaply extirpated by the hoe than by pulling them by the hand. The great improvements that have recently been made in horse-hoes have rendered these implements of great service to the cleaning of drilled grain-crops. The following engraving represents Garrett's horse-hoe, which, though somewhat

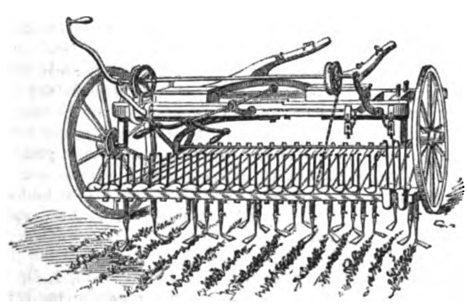


Fig. 17.—Garrett's Horse-hoe.

heavy, is otherwise a most efficient implement. The foresteerage should be attached instead of the shafts, as it is thereby rendered easily managed.

DRAINAGE.

The vast amount of capital which has been expended in drainage within a quarter of a century, attests its utility and necessity. Before the introduction of furrow-draining, stiff and tenacious clays were of comparatively little value. They were cultivated at much expenditure of labour, and the crops which grew upon them were influenced to a great extent by the variations of the seasons. A system by which wet and worthless land could be rendered dry and valuable, was an improvement so patent to practical men, that we need not wonder at the efforts which have been made to effect this end.

Drainage by open ditches was no doubt the first mode of freeing land from superfluous water. The Roman agricultural writers mention the good results arising from covered drains, which were formed of wood and other substances, which served so far to render the land dry. More than a century ago, a large extent of clay-land was drained at narrow intervals in Norfolk and Essex, by putting in brushwood and even straw in the bottom of the drains. The progress of this operation, which is now regarded in many soils as essential to economic culture, was slow and partial, until Mr Smith of Deanston reduced the practice to a system, and shewed the principles upon which its efficiency depended. Through the exertions of this advocate, furrow-draining soon became a *sine quâ non* in the culture of clay-soils.

The great majority of practical men consider the line of greatest fall, or quickest descent, as the best for cutting drains in a field. This, it may be remarked, is also usually the direction for ploughing the land and forming the ridges; so that the drains are commonly put into the *furrows*, and hence the distinguishing appellation, *furrow-draining*. The smaller drains are conducted into larger or *main* drains, instead of each discharging its quota of water into the open ditch. This is rendered necessary, as the mouths of the smaller drains would be more liable to be choked up by the growth of weeds; while the collecting of water into main drains secures a fuller flow to sweep out any matters which might accumulate where the discharge was small.

The most efficient, and at the same time cheaply cut drain, is one represented at fig. 18. It is made so that a pipe of a cylindrical form may be laid along its bottom, which should be of no greater width than what is necessary to its being securely placed.

Fig. 18.

Drains of this form are cut with a set of spades which are of different widths—the broader being used for taking out the top, and the narrowest for the bottom. The one which cuts the last spit is called the *bottoming tool*, and its introduction has effected a considerable saving in cutting drains.

Before the general use of pipes, stones were the common materials with which drains were formed. Mr Smith recommended that they should be broken so small that they might pass through a ring two inches and a half in diameter. From nine inches to a foot in depth was the quantity which was commonly put in. This was found to be a most efficient way of making drains; but unless the stones could be gathered from the fields, or quarried in the neighbourhood where they were used, an immense amount of labour was involved in filling them.

When tiles and pipes were first used, it was even thought necessary to have some gravel, or small stones, placed above them in the drains, for the purpose of enabling the water to find its way into them, as seen at fig. 19. It was soon found, however, that tile-drains were quite as efficient without any stones or gravel; and that they were less liable to be choked up, as the clay or earth acted as a filter in preventing the intrusion of any kind of solid matter.

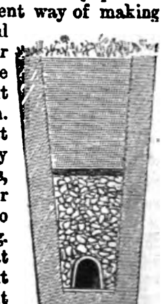


Fig. 19.

Many kinds of tiles and pipes have been tried, but the cylindrical form is now most used. At one time, a bore in the tile of an inch in diameter was thought sufficient, but two-inch tiles are now preferred. They are usually made about fifteen inches in length. The continuity of the drain is maintained completely by *collars*, which should always be used as a means for securing efficiency and permanency.

Much discussion has taken place in regard to the proper depth of drains, as well as the distance at

which they should be placed. Mr Smith at first advocated the making of drains from two and a half to three feet deep, and at intervals of from ten to forty feet, according to the nature of the land. Experience, however, has been gradually favouring deeper drains, at wider intervals. Mr Parkes went the length of recommending a depth of from four to six feet, at intervals of from twenty-four to sixty-six feet. If the deep drainage of land which this distinguished engineer has advocated cannot be successfully carried out in all cases, the graphic manner in which he has described his own experience, and illustrated the principles of draining, has been productive of good results. Even on the most tenacious soils with subsoils of *till*, few now think of having drains less than three feet in depth, though the distance apart should not in many cases be more than from fifteen to eighteen feet.

The mere tenacity of clays is not the element which determines the depth of drains, or the distance at which they should be placed apart. It is now well understood that the success of draining by pipes depends upon the fissures which are produced in the subsoil by the droughts of summer never entirely closing up; and thus minute channels are formed and lead the water into the drains. The coarse tenacious clays which are to be found in the chalk-valleys of England, *crack* readily by the droughts, and form deep fissures, which render them comparatively easily drained. On the other hand, in the moist climate of Scotland, the subsoils which are of *till* are long in cracking; and the drains in such land should not be so deep, and at shorter distances apart. As the properties of clays become better understood and classified, practical men will soon come to be more at one in regard to this important point connected with the economy of drainage.

The principal advantages of drainage are, the deepening of the staple soil and rendering it more friable, so that a superfluity of water which would cause the formation of those chemical compounds that are found in stagnant water, is prevented. The greater depth of mould, and more perfect culture, render the soil more absorbent of moisture in dry periods of weather. As crops can usually be sown sooner on drained lands, they also ripen earlier, and produce more abundantly. In short, while drained land obtains a greater capacity for moisture and manure, it imparts to plants greater capabilities for economically working up the materials which they find both in the soil and atmosphere, seeing they are maintained in the most healthy conditions of growth.

Green Crops.

Grasses, as seen in perfection in rich lawns or meadows, are the most beautiful crops that grow. The constant carpet of verdure which these present in England, is owing to the great number of varieties which come to perfection at different periods of the year. In sowing out fields for permanent pasture, we do well to take a lesson from nature, and sow a mixture of grasses which are valuable, and at the same time indigenous to the soil; for although those grasses which are best suited to the soil, will often, in a series of years, take possession of it, yet time is gained by anticipating nature.

The common varieties of annual and perennial rye-grass are sown when the land is under a system of rotation, and when the fields only remain for one or two years in pasture. These are valuable plants in all the moister parts of the British Islands, but in the south-eastern parts of England they yield little leaf; and the droughts encourage the production of stems which are not relished by stock. For this reason, less benefit is derived from two years of pasture in England than in Scotland.

Italian rye-grass is now grown to a considerable extent in Britain: it is not a good pasture-plant, however, as it grows thin upon the ground, and being shallow-rooted, does not thrive, unless the soil is shaded by its own leaves, which in some measure perform the same ends as pulverising the soil, and rendering it more absorbent of moisture. A liberal dressing of manure in early spring, by sending up a mass of vegetation, which protects the soil from the evaporating influences of the weather, renders the crop less dependent on a supply of rain. Italian rye-grass, for this and other reasons, is better adapted for cutting than for pasturing. It is grateful for liberal treatment, as no other cultivated plant seems to have greater capacities of growth.

Grasses being usually sown out with a grain crop, grow little for a year; their roots have time to run through the soil in search of the earthy matters which the crop requires. Phosphates are therefore seldom used for grass, unless the soil is very deficient of these substances. Nitrogenous manures are thus best suited for all descriptions of grasses.

Clovers grow most freely upon calcareous soils. In the rich marly loams of France, the various varieties of red clover produce fine crops, though much more frequently sown than in Britain. On the limestone gravels of America, red clover is sown every other year, and the land shews no symptoms of clover-sickness. It is on the non-calcareous formations of Scotland that we find this plant so uncertain and fickle in its growth. This we attribute to the want of calcareous matter to correct the vegetable accumulations which take place in the soil, and interfere with the healthy functions of the roots.

Clovers, like grasses, are most benefited by nitrogenous matter, if the soil is favourable to the healthy functions of their roots. A rich dressing of farm-yard manure will sometimes so far counteract clover-sickness by affording the crops a ready supply of earthy matter, which they cannot otherwise absorb, to carry on the assimilating processes in a healthy state. We have known instances of a dressing of two hundredweights of guano, applied to an acre of young clover layers in autumn, after the corn-crop was removed, impart such a vigour to the plants, that they grew luxuriantly next summer, while the clover entirely disappeared from the rest of the field. From the roots of clover running deeper into the ground, nitrogenous manures are most advantageously applied in autumn, as they tend to strengthen the plants, and enable them better to withstand the deleterious conditions by which they are sometimes surrounded.

From red clover sending its roots deeply into the ground, it is comparatively independent of moisture in dry climates. The same observation applies to saintfoin and lucerne, which are invaluable crops in southern latitudes where the soil is calcareous. All these plants, like grasses, maintain a large surface of fresh leaves exposed to the atmosphere, and therefore restore to the soil a supply of vegetable matter, when it has been wasted by tillage.

Beans are only grown on the first-class land in Britain. This arises from the crop requiring a deep soil into which it can send its long tap-roots, and obtain the necessary supply of moisture for its large surface of leaves exposed to the atmosphere. Being an annual, and sown early, it must have a full supply of manure, unless the soil is very rich. The most approved plan of raising this crop in Scotland is to sow in drills or ridges, twenty-seven inches apart, into which an allowance of farm-yard manure has been placed. The common allowance of seed to the acre is four bushels. By this means, the crop can be so cultivated as to permit of the land being cleaned during the growth of the crop.

The bean has a tendency to grow too much straw on the west coast, with comparatively little grain. On the other hand, the extreme heats of the south of England are apt to stunt its growth and induce diseased conditions, which are followed by attacks of insects. The common bean is perhaps as sure a crop and as abundant in its produce on some of the rich lands in East Lothian, as in any part of the island.

Peas are greater favourites in warm and dry districts than in wet and cold ones, where they are more difficult to harvest. They are frequently sown along with beans; but they do not occupy an important place in the rotations of well-cultivated districts, since the general introduction of turnips.

Turnips, for the feeding of stock, arrive at great perfection in this climate. Being sown, however, in that part of the rotation which was formerly occupied with a bare fallow, they form a most expensive crop. In fact, it is not only designed that they should answer all the ends of a bare fallow, but through their growth, and by being usually consumed by stock, an accumulation of vegetable matter takes place on the farm. By this means, a larger quantity of the more valuable produce, such as cereals, may be raised and disposed of.

Turnips are divided into various classes, in each of which there are several varieties. The Swedes, belonging to the most valuable class, have been largely cultivated since the introduction of light manures. White turnips are sown in Scotland early in season; but in England they are usually put in very late. Yellow turnips are the principal class raised in Scotland, as they seem better suited to the low temperature.

In the south of England, Swedes are sown from the end of May to the 1st of July; so late sowing, however, is only practised on light soils. White turnips are sometimes sown there so late as the 1st of August. Swedes and white-globe turnips are sown in Scotland from the 1st of May to the 10th of June; and all the yellow turnips should be put in ten days after the latter date.

The land should be thoroughly cleaned and pulverised before turnips are sown. It is usually drawn up, by the double-moulded plough, into drills or ridges, about twenty-seven inches apart, into which the manure is spread. The manure being covered by 'splitting' the ridges by the plough, the seed is sown by machine on their crests. This enables the young plants to obtain a ready supply of manure, which promotes a rapid growth. When the leaves are about two inches high, Tennant's grubber should be used betwixt the rows; and thinning may then be commenced. This is done by hand-hoes; and the work being light, it is frequently performed by women and boys. Three expert hoers may go over an acre a day. The crops are frequently drill-horse hoed or grubbed during their growth. Earthing up the turnips by the plough is less frequently practised than formerly, excepting upon stiff clay-soils.

To raise maximum crops of turnips, the soil must not only be well cultivated, but highly manured. All those varieties which are early sown should be most liberally dressed with matters yielding carbonic acid and ammonia, for the simple reason, that the longer a plant lives, the more it can digest and assimilate; and further, all those varieties whose growth is extended over the longest period, should have the manure supplied in the most carbonaceous form, which is the best means of slowly yielding up the active elements as the crops require them. Farm-yard manure is best adapted for prolonging the growth of turnips in autumn; and their early growth is best promoted by guano and other soluble nitrogenous manures.

Phosphoric manures are largely and efficaciously employed in raising late-sown turnips. Except on rich soil, these manures can never be relied upon to raise *maximum* crops of turnips, which require more ammonia to do so than any of the cereals. It ought to be borne in mind, however, that in nineteen cases out of twenty in which phosphates are beneficially applied to the turnips, there is really abundance of phosphoric acid diffused through the soil; the necessity of an artificial supply is owing to the small seeds of the turnip requiring a concentrated dose placed within reach of their rootlets, so as to promote their rapid development. Phosphates enable the turnip-plant to form roots and leaves, without which it can neither appropriate the nutrient matters existing in the soil or the atmosphere. Medium crops of turnips may often be got by dressing with superphosphate of lime, in the middle of June in Scotland, when the crops have little time to grow; but this manure, unless combined with matters yielding ammonia, cannot be relied upon to raise a crop of turnips which is sown in the middle of May.

Turnips are either consumed by sheep on the fields in which they grow, in grass-fields, in fold-yards, or feeding-houses. In the vicinity of large towns, they are sold to cow-feeders. This department of agriculture will be treated in CATTLE AND DAIRY HUSBANDRY.

After having the roots and leaves cut off, the bulbs of the turnips are usually stored in heaps about eight feet in width, and piled up as high as they will lie on this breadth of base. They are covered with straw, which is fixed on with ropes, or sometimes a spadeful of earth is thrown on, to prevent the wind blowing it off. Earth, however, is so far objectionable, as it prevents the gases from escaping, and encourages fermentation. The most common error is putting too great a quantity of turnips together, for the heap ferments and the roots decay. Perhaps the most simple and best mode of storing turnips, is to lay them out in a field adjoining the farm-steading, in large heaps, level on the top. The only precaution necessary, is not to make the heap more than two feet in depth. A quantity of loose straw is thrown over the top of the heap, which the first shower of rain is sufficient to beat down so as to require no further fastening. When stored in this way, turnips resist the frosts better than when piled up in pits, which are more exposed to the wind; and they are also less liable to sprout in spring, as the straw keeps them moist and cool. In storing turnips which are to be early consumed, care must be taken not to cart them in when in a frozen state, or covered with hoar-frost.

Mangel-wurzel.—The productive powers of the Swede are more limited in England than Scotland, or, in other words, larger crops can be grown in the latter. Any deficiencies, however, which exist in the root-growing capabilities of the southern climate with respect to turnips, are amply made up by its adaptation to the growth of mangel-wurzel.

The plant having small seeds, and being sown nearly two months earlier than the Swede, must be liberally supplied with manures yielding phosphates and ammonia. With the exception of Italian rye-grass, or the cabbage, no other plant is capable of working up or assimilating a greater quantity of food in a season. The capacity of the mangel for manure is seen when planted on the richest garden-ground, or on spots from which dunghills have been removed. In these circumstances, turnips will only grow to leaves and stems, while mangel will produce large roots. In highly manured land in the south of England, very large crops of mangel are raised, far outweighing the produce of Swedes in this country.

Mangel-wurzel is an inferior plant to the Swede in the climate of Scotland, for, even with the most liberal treatment, the crops are comparatively light. In our colder climate, also, the plants have a much greater tendency to seed than in the south. In the inferior produce of the mangel, and this tendency of the plants to seed, the effects of the lower temperature of Scotland are more clearly exhibited than by any other cultivated crop.

One of the chief elements that hasten the seeding of plants, is a scanty supply of food. The growth of the cabbage, for instance, in its leafy state, is only protracted by a liberal allowance of manure. Indeed, the abnormal supply of food that vegetables obtain in their cultivated condition, is the principal influence which alters their habits of growth. Liberal manuring, and a soil of good physical capacity, are well known to have the effect of protracting the period of bulbing in

turnips; while the opposite conditions, light manuring and a dry soil, cause the plants to flower.

It is only a modification of the same principle that we have stated above that is in operation, when mangel flowers in summer in colder climates. Plants, like animals, may be starved by cold as well as by a want of food. A want of moisture, also, has the effect of making vegetables form flowers. Dry and cold weather, conjoined with a short allowance of manure, have a great influence in hastening the seeding of plants.

Plants, as formerly pointed out, are more independent of a supply of food to their roots in summer than in spring, owing to their facilities for abstracting food from the atmosphere being greater in the one season than the other. The healthy functions of mangel-wurzel can only be carried on at a higher temperature than what is necessary for the turnip. To delay its seeding when the temperature is low, it must be supplied with a greater quantity of manures in a more concentrated state. Thus, mangel is not so liable to flower in Scotland when it grows upon the spots from which dunghills have been removed; neither do those who dress the plant with large quantities of liquid manure have occasion to complain of flowering. So, in warmer climates, the increased vitality of the plant, by making it less dependent on an extra supply of manure, retards the flowering process. At the same time, if the plant is under-manured, it will seed in warm as well as in cold climates. The principle of a higher temperature delaying the period of flowering in plants, is strikingly exhibited in the case of our cereals, inasmuch as wheat, barley, oats, and rye, have no tendency to seed when sown in summer in southern latitudes.

Potatoes usually enter into the rotation on farms where they can be easily sent to market. Being a bulky article, however, they cannot bear in ordinary years the cost of transport for a great distance by carts. It is in the neighbourhood of large towns, therefore, that they are prominent crops in the rotation. The usual period of planting in the British Islands is from the 1st of March to the middle of May, and of harvesting, October and November. It is customary to plant eyesets, or cut pieces of potato, each having an *eye* or point of germination. They are planted at a distance of eighteen inches apart in drill-furrows (made by the double mould-board plough), previously well dressed with farm-yard manure or guano. After the plants appear above ground, they are as frequently grubbed, earthed up, and hand-hoed, as may be required to keep the ground loose and free from weeds. The disease which so generally attacked this crop in 1845, has, by its repeated appearance, rendered it precarious. Being very susceptible of frosts, potatoes must be stored carefully in pits covered with straw and earth.

White Crops.

Wheat is the most important of all the cereals, and we believe it grows over a wider range of latitude than any other plant. In Egypt, it is raised in the very centre of the Tropic of Cancer, and on the continent of Europe as high as the 60th parallel. It is right to observe, however, that this extreme range is obtained by its growing in the one country in summer, and in the other in winter. Indeed, it is not a plant that requires a high mean temperature before it puts forth its ears; it even exhibits little tendency to produce seeds if sown during the heats of summer in France or America.

In Britain, a great number of varieties of wheat are cultivated. Spalding, Kessingland, Lammas, Burwell, red wheats, are great favourites in the dry climate of England, as they yield more grain than any of the white varieties. The farmers consider that they are usually as well paid by the larger quantity of grain, though the quality is inferior. Hopetoun, Hunter, red chaff white, red strawed white, and Fenton, are the most common varieties cultivated in all parts of Britain. April or awny wheat is largely sown on inferior soils in Scotland, where it is quite as sure a crop as barley, and the straw is as good for fodder.

From six pecks to two bushels of grain are usually sown by the drill in the south of England. Less than the latter quantity is seldom sown in Scotland; and when sown on the common furrow, four bushels is the common allowance after green crops. Spring-wheat should be sown thicker than autumn, to assist in hastening on the crop to maturity, and in promoting a finer sample.

Wheat is generally sown in the southern and eastern counties of England after clover lea. In all dry climates, the decaying matter which clover-roots afford seems to be best adapted for feeding the wheat-plant during the long time it is in the ground. It ought to be constantly borne in mind that, in manuring a plant, we should be guided by similar principles as in feeding an animal. Theoretically speaking, every one must allow that no more food should be supplied to plants or animals than they are capable of daily digesting or assimilating. Manures, therefore, should be of such a nature as to afford nourishment to plants during their whole period of growth. Plants which do not grow rapidly, should be supplied with manures that slowly yield up their active substances. Autumn-sown wheat, therefore, in dry climates is best manured by a clover sod.

As a general rule, the growth of autumn-wheat is most economically promoted by carbonaceous substances; such as clover roots, the refuse of the manures which have been applied to green crops, or by rape cakes, and inferior qualities of guano, which only yield up their ammonia during the growth of the crop.

With spring-sown wheat, a different course must be followed. Its growth being more rapid, the ammonia should be in a form that can be more readily assimilated, and hence Peruvian guano is the best application for this crop. The most soluble manures, on the other hand, such as nitrate of soda, are best fitted for top-dressing wheat in spring, for the rapidity of growth which ensues in early summer enables plants to digest a larger quantity of food in a given time.

The value of manures is rated by the quantity of ammonia (or nitrogen) which they contain. But so much is this principle held in abeyance to the *form* in which this element exists in manures, that even before the recent rise in the price of guano, nitrate of soda was largely used for top-dressing wheat, though nitrogen in this form cost the farmer double the price per pound that it did in Peruvian guano. Rapid growth and soluble manures must go together; for this reason, inferior guanos, which yield up their nitrogen more slowly, are preferable, for autumn dressings, to Peruvian, in which the ammonia is in a more soluble form.

In all hot countries, the common varieties of wheat can only be sown with advantage in winter; even in the eastern counties of England, where the range of the thermometer is considerable in May, these varieties do not succeed so well when sown in spring as they do in Scotland and the western counties of England. Thus Mr Read, in his excellent report on the farming of South Wales, in the *Journal of the Royal Agricultural Society*, says: 'Spring-wheat flourishes well in this climate, and has been long cultivated with success. Instances of wheat being sown on the 1st of May, and ripening within nine days of barley sown on the same field, and at the same time. An intelligent farmer last year did not finish sowing his wheat till May, and even with that drenching sunless summer, it was cut in the early part of September, and produced thirty-two bushels to the acre.' On the other hand, common wheats yield a small return, even in Suffolk, when sown so late as February.

From the circumstance of the growth of wheat being extended over a longer period than any of the other cereals, and of its growing in a colder season, it must be more liberally manured with substances which

slowly yield up the nitrogen they contain. For this reason, it has always been regarded as a very exhausting crop, requiring more manure than any other. But owing to the fact of the soil requiring to be dressed with substances that only slowly yield up their active principles to the crops, the soil cannot be exhausted by crops of wheat to the same degree as by crops of inferior grains, which require less manure, but which leave less in the soil, and thus really exhaust it more. Turnips grown by market-gardeners require a great deal of manure, and are justly regarded as exhausting crops; but from the large residue of manure left in the soil in the mere forcing of these crops, the land is still left in a richer state than when crops of turnips are grown by superphosphate of lime. Instead of proprietors of land restricting the quantity of wheat on their farms, they would do well to encourage its extension, seeing the growing of wheat is actually a test of the good condition of the soil.

Wheat is liable to certain fungous diseases, as, for example, smut, mildew, and rust. The last two it is not so much in the power of the farmer to prevent as the first; they are more common in England than in Scotland. Early or thick sowing tends to impart conditions which are unfavourable to the appearance of these diseases. Smut is best prevented by watering the wheat with a solution of sulphate of copper—one pound of this substance being sufficient for half a quarter of wheat; it should be dissolved in as much water as will thoroughly wet the grain, which, as soon as dry, may be sown.

Rye is usually grown on light sandy soils, and requires less care than wheat. It is frequently sown along with winter tares in England to be cut for soiling, and when sown on the wheat stubble, is extremely useful as food for breeding flocks in spring, as it comes forward earlier than tares, and affords good pasture when other substances are scarce.

Barley.—There are several varieties of this grain cultivated in Britain: the early English, Annat, Stirlingshire, chevalier, and *bere*, are the most common. This grain grows best upon a rich mellow loam, moderately retentive, where the culture has been careful. It rarely succeeds where the soil is stiff and wet. On the heavy clay-soils of Essex and Suffolk, excellent crops of barley are got after summer fallow. The ground being ploughed up in autumn, the mould which is pulverised by the frosts affords a fine seed-bed. The surface is usually scarified before the seed is sown by drill. An intelligent agriculturist, who farms heavy clay-soils in Suffolk, writes: 'When new year has commenced, the Suffolk plan is never to let a favourable opportunity escape for drilling barley, if the land is prepared.' When land is in good condition, early sowing is to be preferred, as heavier crops and finer quality are thus obtained.

On the light soils of the southern counties of England, barley is usually sown after the turnip-crop, which is generally eaten on the ground by sheep. After the land has been trodden, it must be carefully prepared by two or more ploughings, rollings, and harrowings, to pulverise it, and render it more retentive of moisture. In the dry climate of Norfolk, the farmers expend a great deal more labour in preparing the land after turnips, than they do in the moister climate of Scotland, where turnip-land is rarely ploughed more than once. Owing, also, to the greater heats and droughts in the south of England, good quality of barley is rarely got when sown after the middle of April.

It is much easier to over-manure barley in moist climates than wheat; hence the latter is more frequently sown in the western counties after turnips eaten on the land by sheep. Much land is well adapted for the growth of the finest quality of barley along the east coast of Scotland. Barley is now sown in Scotland as soon as the land is in a fit state to receive the seed. On rich and dry soils, barley is rarely injured by spring-frosts; it is only on weak soils, or such as are out of condition, that complaints of this nature are heard of.

On many of the trap-loams in Scotland, barley is sown after wheat; in this case, it is generally sown late, as the more genial temperature acts as a compensation for a richer soil. This is in accordance with the principles enunciated under the head of the Meteorology of Agriculture. Early-sown barley is best manured by Peruvian guano, as plants growing in the colder season demand a more liberal supply of food. If barley is sown in May, less ammonia should be applied, as at that season the crop can rely to a greater extent upon the atmosphere, if it obtain a ready supply of phosphoric acid. Thus superphosphate of lime is generally of little use when applied to barley sown in March, but has often good effects when sown in the end of April or May.

The six-rowed variety of barley, called *bere*, is now chiefly confined to the northern counties of Scotland. It is the most hardy of all the kinds of barley, and being stiffer in the straw, it is not easily laid by rains or over-luxuriance.

Oats.—Of this grain there are many varieties, which our space prevents us from particularising. The potato-oat is an early and productive variety on low and rich lands; indeed, it has gradually extended as the fields have been better manured. Though the oat is usually considered to thrive best in moist climates, the level land along the sea-coasts of Scotland, such as in the plains of the Lothians, produces the most grain and finest qualities. Many varieties are suited to climates which are too wet and cold for other grains. The oat is a grosser-feeding plant than any of the other cereals, and can be more freely dressed with nitrogenous manures. In the rotation, oats succeed grass or clovers, and in moist climates, leave the land much cleaner than when wheat is sown. From four to five bushels of seed to the acre are sown broadcast, and from three to four when drilled. The usual time of sowing is from the beginning of March to the end of April. If the land be in good condition, the earlier the better.

Haymaking.—When the grass has arrived at or near its full growth, but before the seed is perfected, it should be cut down by the scythe for hay. A short time after being mown, it should be turned over in full swathes, without being scattered. If not in a fit state to be cocked the first day after cutting, it should be put into small handcocks as soon as its state of dryness will allow; from these it should be gathered into larger ones, and when its condition permits, put into tramp-ricks. The gathering of the hay is generally performed by women and boys, some carrying, and others raking

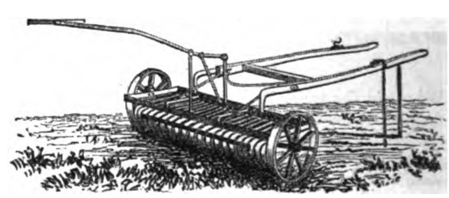


Fig. 20.—Horse-rake.

up what may remain. The horse-rake is now much employed in gathering hay, and from the construction of the teeth, gathers fewer stones or earth than any which has yet been invented. Let it be remembered that the less the hay is exposed to the sun, the better is its flavour and strength. In wet seasons, the utmost care will be required not to stack the hay while moist; for then, like moist sheaves of grain, it will heat, and either burst into a flame, or be seriously damaged in quality. The criterion for good hay is, that it should be greenish in colour, be perfectly dry, and possess a sweet odour and saccharine taste.

REAPING—HARVESTING.

The ripeness of grain is shewn by the straw assuming a golden colour from the bottom of the stem nearly to the ear; or when the ear begins to droop gently, the corn may be cut. Although the straw may be green from the ear for some distance down the stem, yet if it be quite yellow at the bottom, and for some distance upwards, the grain requires no further nourishment from the earth, and if properly harvested, will not shrink. These indications of ripeness may suffice for wheat, barley, and oats. In peaty soils, however, the ears of oats and barley usually ripen before the straw, which often requires to be cut in a green state.

Reaping.—It was formerly the practice to cut grain with a saw-edged sickle; but this has given place to a larger instrument, with a smooth edge like a scythe. The reapers are usually divided into bands of six or seven, with a binder to each band. When the ridges are less than eighteen feet broad, three reapers are usually placed upon each ridge, the middle reaper making the bands with which the sheaves are bound up. When four reapers are placed upon one ridge, as is usually the case when the ridge is eighteen feet broad, two bands are laid upon one ridge; and two binders are enabled in this way to manage twelve reapers, placed on three ridges, stooking the corn all in one row upon the middle ridge. When the crop is very strong, however, it is often found necessary that each binder should stook by himself. In harvesting oats and barley, each shock or stook is formed of ten sheaves placed in two rows, the head of each sheaf leaning upon the opposite one, and a sheaf on the top at each end. They stand usually due north and south, so that each side may receive equal benefit from the sun. The straw of wheat being longer than that of oats and barley, the stooks of the former are made larger, having six sheaves in each row, and one on the top at each end. When the crop is thin, half-stooks are frequently set up; and to forward the drying process, the end-sheaves are now generally omitted when the weather is good; but this should never be done where the climate is uncertain, as it exposes the corn to rain.

Oats and barley are now frequently cut with a scythe, which is either plain or furnished with a bow or cradle, in order to lay the grain evenly in one direction. Wheat is almost universally cut with the sickle; and if the weather keep good after this operation is performed, it will be ready for stacking in the course of five or six days. Barley is frequently cut with the scythe in England, but the sickle is more commonly used in Scotland. Barley and oats require to lie ten or twelve days, as they are more or less mixed with clover, before being ready for stacking. The clover ought to be completely withered before the corn is stacked; and, indeed, it requires the greatest caution on the part of the farmer in ascertaining whether his crops are in a proper state for being carried to the stack-yard. The best way for judging of this is to take out a handful from the centre of the middle sheaf on the lee-side of the stook, repeating this on several parts of the field; and if the knots or joints of this are dry and shrivelled, the crop may be led home in safety. All corn crops should be cut as low as possible, for by this a great addition is made to the straw, and consequently to the future manure.

The process of reaping, either with the sickle or the scythe, is necessarily a tedious one; hence the repeated attempts which have been made to use machinery to expedite it, and relieve the farmer of much anxiety, by enabling him to house his crops with rapidity. It has been matter of surprise to some that machine-reaping has not been generally adopted; but a moment's consideration will shew that there are difficulties in the way which prevent machinery being so easily applied in this as in other departments of farm-practice. Thrashing, for instance, is unvarying, or nearly so, in its operation; the material to be operated upon being generally presented in nearly always the same circumstances. Not so with reaping—the material is continually changing its condition; and the difference between a rainy day and a dry one—between hilly ground and level—is just all the difference that is required to make the material either that which affords facilities to the machine in cutting, or, on the other hand, of throwing such obstacles in the way as to render it almost an impossibility to cut it at all. In view, however, of what has already been effected, and of the increased attention now directed to it on the part of mechanists and agriculturists, we have no doubt that in a short time the difficulties in the way will be removed, and a reaping-machine take its place in the implement-department of every well-managed farm. Since the exhibition of 1851, in London, the reaping of grain by machinery has attracted a great deal of attention. The American reapers, exhibited there, shewed that the mode of cutting the grain might be simplified, though these machines were in a comparatively imperfect state, and not fitted for the requirements of English agriculture. The following wood-cut represents the cutting part of Hussey's reaper. The cutters are set in motion by the machine as it progresses.

Fig. 21.

Bell's original reaper was a much more perfect machine than any of the American machines: as it laid down the corn so that it could be easily gathered up for binding. The liability of the cutting-knives to get out of repair was its principal defect. It was soon discovered, however, that Bell's might be greatly improved by M'Cormack's mode of cutting. A large number of machines have been made on this combination, known as Crosskill's and Bell's reaper. Owing to the great weight of this machine, many makers are striving to manufacture an implement of less weight, and requiring less power. This important point has already been so far attained by Dray's Hussey. The number of ingenious mechanicians who are now directing their attention to the making of reapers, leads us to expect that a still more efficient implement will be produced than any that are at present in use.

Stacking.—When the crop is thoroughly dry, it is led home to the stack-yard on open spar-built carts, and built into stacks so constructed as to afford complete shelter from the weather. The stool or bottom upon which the stack stands was formerly made of loose straw or brushwood; but in the best managed farms, it is now the practice to construct the stacks on stands made of stone or brick, or upon pillars made of stone or cast iron, sparred across with wood or iron. These stands are formed so as to prevent the access of vermin, which is calculated to effect a saving of two bolls in thirty; and many

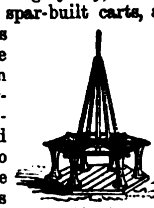


Fig. 22.

have funnels from the top to the bottom of stacks, to admit a free current of air. In Scotland, the stacks being mostly round, a sheaf is first placed on its but-end, in the centre of the bottom or stand; around this, others are placed, also upright, but with a slight inclination of the head inwards, until the stand is nearly filled. The stacker then places a layer of sheaves horizontally on the outside of these, lying on their sides, the ear-ends inwards; and pressing them together with considerable force, he continues to lay on rows until the outside sheaves are as high as those standing on end. The whole stack is filled up in nearly the same manner, the ear-ends of the sheaves being always inwards, with a regular inclination downwards and outwards to their butts, and the centre of the rick being higher, and not so compressed as the outside. Proper attention to the sloping of the sheaves is necessary from the foundation of the stack, but particularly so at the intake of the inner layers, that part being always left more open. When this is done, the stacker sets up an outside circular row of sheaves, having their but-ends projecting a few inches beyond the body of the rick; after which the outside layers come gradually inwards, until the roof is drawn to a narrow circle, when two or three sheaves placed upright completely fill up the stack. The topmost sheaves are then firmly bound with a few turns from the middle of the straw-rope, the two ends of which are fastened on opposite sides of the stack. When carefully built and thatched, a stack will completely keep out rain, and be quite secure from high winds. Materials for thatching, and straw-ropes, should always be made before harvest, so that no delay may arise from this in the event of wet weather. The thatcher stands upon a ladder, placed on the sloping roof of the stack, and lays on the straw in handfuls, from a quantity placed within his reach. One end of the straw he thrusts into the butt of a sheaf, and the other end hangs over the stack. He thus progresses upwards, making each handful overlap the other; and having drawn the top to a point, he binds the whole covering securely down with a series of tough oat-straw ropes.

Stacks are sometimes constructed in England on a timber platform raised upon stones, and over the stack the framework of a perfect barn is placed, which can be either tiled or thatched. This is said to afford greater security to the crop, and to be less expensive than annually thatching. The price of erection is said to be comparatively trifling, when the convenience of such buildings is considered; and they have been known, when well put up, to last for thirty years.

Thrashing is either performed with the flail or the thrashing-mill. The use of the latter we by all means recommend in preference on arable farms of above one hundred acres in extent. The machine may be driven by water, horse, or steam power, according to circumstances. Several improvements have been made on thrashing-mills since their first invention. The unthrashed corn is now made to pass through two revolving rollers, while it is acted on by beaters placed lengthwise upon a large cylinder or drum, which moves at the speed of 2500 feet in a minute. The great essential in thrashing is to have regularity of motion, and the grain to be equally fed into the rollers. One man should be employed to feed in the corn; one man, or two boys, to carry the sheaves; and a woman to untie and place them on a table near the feeder. Other persons are employed in raking and carrying the thrashed straw to the straw-house, where it is built. When the machine is driven by steam or water, it is generally the case that one or two winnowing-machines, according to the power employed, are attached to the thrashing-mill; and thus the expense of preparing the grain for market is considerably lessened. A powerful machine will thrash from two to three hundred bushels in nine

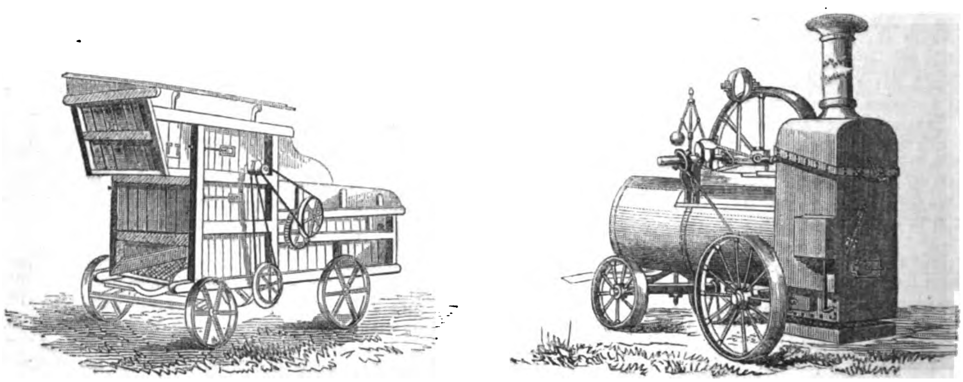


Fig. 23.—Clayton and Shuttleworth's Thrashing-machine and Portable Steam-engine.

hours; and allowing for wages and wear of machinery, the expense of thus preparing grain for the market is under one penny per bushel.

Various improvements in thrashing grain have been introduced. The well-known *peg-drum*, with or without feeding-rollers, effects a saving of power, and does not break the straw so much as the common beater, in separating the grain. The small, high-speed beating or rubbing drum, so much in use in England, has lately been introduced into Scotland; and, as its construction is better understood, it is giving greater satisfaction. On the large farms in England, portable steam-engines, though more costly than the fixed, are preferred by farmers, who have yards for feeding cattle in various parts of their holdings, for the purpose of effecting a saving in the carting out of the manure. The above cuts represent Clayton and Shuttleworth's portable engine and thrashing-machine.

Winnowing is a process performed by the aid of wind, by which the chaff of corn is separated from the grain. Winnowing-machines, or fanners, as stated before, are sometimes attached to thrashing-mills, and they are a necessary appendage to every farm, either in conjunction with the thrashing-mill, or separately. Some farmers winnow their grain by hand-fanners, which are thought to be steadier in the motion than when driven by machinery, and consequently the grain is more thoroughly cleansed. After thrashing, the grain is regularly dressed in the clean-corn room by means of fanners, riddles, and sieves; and this final dressing is regulated according to the state in which the grain comes from the thrashing-mill. By the process of winnowing, chaff, bits of straw, the seeds of weeds, and other refuse, are separated from the grain; and it is a wise precaution to boil the latter before putting them on the dunghill, which will effectually destroy their vegetative powers.

The different qualities of grain are also separated from each other, by which it is rendered more valuable than when the good and bad are mixed together. The thorough cleaning and dressing of grain are of great importance to the farmer; and he will find it to add to his profit in the end to have this effectually done.

Barley undergoes a process called *hummelling*, by which the awns are broken off from the grain. The machine is composed of a vertical spindle enclosed in a cylinder, and furnished with arms which act upon the grain. It is sometimes attached to the thrashing-mill, and sometimes driven by a separate power. The grain is put in at the top of the cylinder, and as it passes through, the awns are broken off by being struck by the arms attached to the spindle. A more simple process is, after the barley is thrashed, to take off the head of the drum, and put on another cover of tin, perforated with small holes about three-sixteenths of an inch wide. The barley is passed through the rollers, and by this the awns are rubbed off.

After being dressed and made ready for market, grain should be kept very dry, in a granary free from damp, and impervious to the incursions of vermin. It is, however, the best plan not to thrash grain till it be required for market, because it loses in weight, or shrivels in bulk, by keeping. It also loses in weight, though to a much less extent, by being kept long in ear in stacks; and therefore the sooner grain is thrashed and carried to market, the greater will be the return, supposing there be no rise in price.

ECONOMY OF ROTATIONS.

The majority of the crops which have already been noticed are cultivated to a greater or less extent on most farms; but peculiarities of soil and climate, distance from markets, besides many other circumstances, conspire to render particular crops more prominent objects in the rotation of one district than another. Indeed, the practical economy of British rotations is a most interesting subject, though one that has received comparatively little attention. Our space being necessarily limited, we shall only discuss the more important heads.

Norfolk has long been celebrated for its agriculture; and though the art has made great advances within the last century, it is curious that the rotation of crops in that county has undergone little change during so long a period. Mr Caird has fallen into the common error of attributing the founding of the Norfolk four-course rotation—turnips, barley, clover, wheat—to the late Lord Leicester; whereas the truth is, this rotation was generally practised long before his lordship became a farmer. Mr Coke only came into possession of his estate in 1776; but Arthur Young made his celebrated tour through Norfolk six years before this date, and he then gave the following account of this rotation: 'It is a noble system, which keeps the soil rich, though some farmers depending on their soils being richer than their neighbours'—for instance, all the way from Holt by Aylsham down through the Flegg Hundreds—will *steal* a crop of peas or barley after wheat; but it is bad husbandry, and has not been followed by those who have made fortunes.' In recommending a change in this system of cropping, Arthur Young shews us that *high farming* had already taken hold in Norfolk. The modern improvements that have taken place, have not been in the direction which this accurate observer anticipated. He writes: 'If I may be allowed to hazard an idea on this point, I should venture to condemn the ploughing up the clover the first year, and for these reasons: it is exhausting the land more; two crops of corn in four years exhaust much more than two in five years; hence appears to me the *modern* necessity of buying oil-cake at two guineas an acre.' This is admirably stated, and shews that, at that period, money-making farmers had adopted the shorter and intensified system which was afterwards carried out by Lord Leicester.

It is rather singular, however, that Lord Leicester, as it would appear, had been struck with Arthur Young's reasoning, and had pursued the very course he recommended; for, in 1783, Arthur Young paid a visit to Holkham, and his lordship was following the five and six course shift, or of having two or three years in grass. The objections to this system were, that it allowed the land to become foul, and three or four ploughings instead of one were necessary to bring it into a proper condition for wheat. Commenting on this practice, Young again writes: 'On our good lands we never think of giving more tillage than one ploughing, and get as fine crops as can be seen; now, the necessity of tearing a loose soil to pieces, the fault of which is too great looseness, while no such necessity exists on much stiffer soils, appears to be quite a paradox.' This extra cultivation of the grass-land, however, has always been found necessary on the lighter lands in the drier counties of England for obtaining crops of wheat, when the land has been allowed to remain for a longer period than one year in grass. Thus the Norfolk farmer is in a great measure shut up to the necessity of having two white crops in four years, and of expending large sums in the purchase of cake for feeding, and of artificial manures.

The climate of Norfolk is not so well suited to the growth of turnips as the west of England, Ireland, or Scotland, but the turnip is a more prominent crop in Norfolk than it is in any of those places. Nowhere in Scotland is it raised to the extent of one-fourth of the arable land. Turnips are an expensive crop, and in the feeding of stock, do not directly pay the farmer for raising them. They, however, are a necessary part of the system in Norfolk, even when sown to so great an extent as one-fourth of the arable land.

In the Norfolk rotation, one-half of the land is in equal parts of barley and wheat, which are both high-priced grains. The raising of these two grains can better afford a loss to be made upon the turnip-crop, than if oats had taken the place of either the one or the other. In the moister climates, which only admit of inferior grains being sown, the turnip, though easily raised, never occupies a fourth of the extent of the farm, as is the case in Norfolk. The raising of the crop for feeding cattle or sheep does not pay of itself; and hence, on farms where oats are the principal grain raised, pasturing the arable land for more than one year is the course always followed.

It is highly important to draw the distinction between the cattle crops that pay the farmer, and those that do not. Mr Mechi and Mr Caird have expressed very different opinions on the economy of feeding—opinions, indeed, quite antagonistic. The former maintains that live-stock do not pay at all, while the latter affirms that they are the most lucrative sources of profit to British farmers. The truth, however, is, that such crops as turnips, which are raised at a great expenditure of labour and manure, do not yield, on the average, a direct return equivalent to the expense of raising them. On the other hand, grasses and clovers, which grow without cultivation and manure, yield a return in the feeding of stock equivalent to the landlord's rent and tenant's profits. Looking at the expenses connected with the two crops, we have always thought that the ordinary rates which a grazier will give for a field of turnips and a field of grass, are sufficient to guide us on this question.

A large breadth of turnips can only be economically raised as part of a rotation, where, as is the case in Norfolk, barley and wheat are raised to a great extent. It is for this reason that agricultural tourists, from the days of Arthur Young, have remarked with surprise, *that this crop is never raised so extensively in those districts which have a climate particularly well suited to it, as it is in Norfolk.*

Turnips, being an ameliorating and less profitable crop, are never so extensively cultivated on rich land as upon poor. On rich land, potatoes or beans, yielding more profit, are substituted; so that even where the soil is well adapted for turnips, this crop, on high-priced land, does not usually exceed one-sixth or one-seventh of the arable land of the farm.

It would be out of place, in this short article on agriculture, to enter particularly upon this interesting subject; and we shall only contrast the Scotch and Welsh systems of rotation with the Norfolk.

In moist climates, the general system is to rely to a great extent upon grasses for renovating the fertility of the land, when it has been exhausted by crops of cereals. Though cereals, as is well known, are inferior in quality in moist climates, yet they are there raised at less expenditure for manure. This circumstance, and the less amount of labour expended in cultivation, form a certain compensation, so that arable land is fully as valuable when devoted to cereals in the west side of the island as on the east. These principles are well brought out in Mr Read's essay on the farming of South Wales, contained in the *Journal of the Royal Agricultural Society*. In answering the question, 'How far it is desirable to adopt the four-course shift in the moist climate of the west of England?' he writes:

'The only artificial manure that has been extensively tried is guano, which has been found to answer admirably for corns, root-crops, and grass; indeed, the effects are sometimes double those which are produced by the same manure in the east of England. The great activity and increased luxuriance which are imparted to all crops by the application of good fertilisers, are conspicuous to any one who has seen the small returns produced by heavy dressings given to the gravels of Norfolk. The Welsh farmer, therefore, should adapt his system of improvements to his own soil and climate, and not to that of Norfolk, or any other totally different portion of the kingdom. It is always considered abominable farming to take two white straw-crops in succession; still, with moderately high farming, on good soils in this country, that abomination may be successfully practised. Experience has proved that, on the better lands, barley, after a drawn crop of turnips, will frequently lodge. Although the following course cannot be defended on the principles upon which a rotation of crops is founded, yet it is one best suited to the good land of this district: 1, turnips; 2, wheat; 3, clover; 4, wheat; 5, barley.'

In Scotland, the necessity of having a large extent of land under turnips was not felt up to 1813, the date of Sir John Sinclair's Appendix to the General Report. Before the opening up of the London market by steam-navigation, the feeding of cattle was not much followed. In 1813, the six-course of rotation was most generally adopted on the best farms in the Lothians—that is, 1, fallow; 2, wheat; 3, clover; 4, oats; 5, beans; 6, wheat. On the lighter and fertile soils, the five-course was not uncommon: 1, fallow; 2, wheat; 3, barley; 4, grass, one or two years; 5, oats.

The modern improvement in these systems has been the substitution of turnips for the bare fallow. If this crop does not pay for all the expenses of its cultivation, it pays for a large part, and increases the supply of manure on the farm.

The Berwickshire four-course shift is not so productive of wheat or barley as the Norfolk. Even were so large a proportion of the arable land in turnips as a fourth, it is difficult to obtain a fourth of the land in wheat without curtailing the extent of barley. Wheat not generally succeeding well in Scotland after grass-crop, the rotation is often: 1, turnips; 2, wheat or barley; 3, grass, one or two years; 4, oats.

One great drawback to Scottish agriculture is, the difficulty of increasing the breadth of barley and wheat on lands where it is inconvenient or unsuitable to raise either beans or potatoes. Wheat in Norfolk cannot be taken with advantage after two or three years' grass, but oats can be so with great success in Scotland. But unless upon soils of good physical capacity, oats do not form so profitable a crop for forcing as wheat; and hence the expenditure for manures on oat and barley farms is much less in Scotland than on the wheat and barley farms of Norfolk.

It is often asserted that the climate of Scotland is unsuited to the growth of wheat, and that the inferior grains, oats and barley, can be raised with greater advantage. The practice of farmers who cultivate the best soils does not countenance such an idea. In Sir John Sinclair's Appendix to the General Report, a statement given of the produce of a Scotch acre, sown with the three kinds of grain, in Clackmannan, for fifteen years—from 1781 to 1795—shews that the wheat-crops during that period were more profitable than the other grains, which were also more subject to variation in their amount of produce. Thus: Oats varied from 49 bushels to 26; average, 42; value, £5, 9s. 4d. Barley varied from 57 bushels to 18; average, 39; value, £6, 4s. 5d. Wheat varied from 43 bushels to 25; average, 35; value, £9, 15s. 5d.

The prices were low during the whole series of years, with the exception of the last. The superiority in value of the wheat over the other two crops is considerable. The results indicate that, although it may be profitable to cultivate spring crops under an inferior system, improvements in Scottish agriculture, where the climate is suitable, must evidently take the direction of increasing the extent of the two most valuable cereals, barley and wheat; for if no potatoes are raised for export, these are the only grains which will afford the basis for higher farming, on the same principle that potato-farms require more capital or can be higher farmed than where cereals only are raised. But the other aspects of this question will be best treated in the paper on CATTLE AND DAIRY HUSBANDRY.

FARM-BUILDINGS.

Each farm must possess a residence for the farmer, cottages for the servants, and buildings for the stock and crop. The *farm-house* should be commodious and plain, with an extent of accommodation about equal to that which those have who are engaged in commercial pursuits in town, employing the same amount of capital. The cottages for the servants should also be plain and roomy, and internal convenience should be more studied than outward ornament.

Proper offices are essential to the economical disposing of the produce of the farm. The corn crops are usually thrashed there, and a large portion of the green crops is consumed by stock, which must be well provided with shelter from the cold. When few turnips were raised, and few cattle fed, large open courts were best suited for converting the straw into manure. Now, however, in many cases, the excrements of the stock are sufficient for wetting all the straw, and hence has arisen the practice of box-feeding. In this case, the solid and liquid excrements are carted out along with the straw, which acts the part of a sponge. This is, no doubt, an excellent way of manufacturing home-made manure. It takes a considerable quantity of straw, however; and as more green crops are raised and consumed on the farm, sufficient straw cannot be got to absorb all the liquid; hence a saving of the straw is effected by stall-feeding, when the excess of liquid must be collected into tanks, and otherwise disposed of. When it is remembered that ammonia cannot be purchased in the market at the present time under £60 per ton, the utility of husbanding this material when it is freed as the excrements of the stock decompose, must be self-evident. If the solid excrements are kept in a compressed state, no fermentation takes place; and if the manure is of good quality, it should be applied to the fields at once. Liquid manures should be carted out,

or distributed by pipes, when the plants are in a growing state, otherwise part of it will be washed out of the soil. Covered farm-yards are rapidly extending over the country. It is the cheapest and best way of erecting farm-offices. Our frontispiece represents a bird's-eye view of a 'Model Farm-steading,' designed by Mr J. Lockhart Morton, for a farm of 500 acres, and a model of which was commended by the judges of the Berwick cattle-show in 1854.

The steading is on the covered principle, all the various departments being under one roof. It will be seen by the ground-plan on page 518, that the food-preparing houses are ranged as convenient as possible to those in which the food is to be consumed, and that the relative positions of every other department have been carefully studied. This is the great point to be attended to in the formation of all homesteads, whether open or covered.

Ventilation.—'Without good ventilation,' to use Mr Morton's own words, 'a covered homestead must be a nuisance. All the apartments are so arranged that, unless fresh air circulate through them, and they are kept perfectly clean, there must constantly be unwholesome effluvia in the interior—the foulness of one apartment being communicated to another. The system of ventilating this model farmstead is certain to give most satisfactory results, if only ordinary care be taken to keep the different houses as clean as they ought to be.' His arrangements are briefly as follows:

Under each feeding-passage is built a circular ventiduct or air-shaft, thirty inches in diameter; in connection with these there are feeding-mouths with gratings on the outside of the building; inside, there are numerous finely perforated gratings; by sliding-valves, wrought by a cord and pulley, the supply of air is regulated. Besides these, there are gratings every ten or twelve feet along the exterior walls, perforated so as to admit near the floor a considerable quantity of air. The roof, too, is provided with ventilators with vertical spars, and openings are left here and there in the sarking to act as induction and eduction tubes. The numerous perforated apertures throughout the building will admit twice the quantity of air required for the respiration of the animals, and are so under command that they will neither admit flies in summer, nor too large a supply of cold air in winter. A covered steading, somewhat similar in construction to Mr Morton's, has been erected at Glen, in Peeblesshire, where the ventilation of the enclosed cattle-courts, &c., is admirable.

We would only remark, that to carry out this principle of ventilation is somewhat expensive. A cheap and yet efficient system of ventilation for cattle, is to cover the yards with pan-tiles without plaster or lath. Those who wish to see farm-offices economically erected, at the same time combined with the most perfect ventilation, we would recommend to visit some that have been lately built on the property of Lord Kinnaird, Rossie Priory, Perthshire. As a general rule, farm-steadings are erected at too great an expense.

Choice of a Farm.

Farms, as to size, are usually divided into small farms under 100 acres; moderate-sized farms from 100 to 250 acres; and large farms of from 250 to 1000 acres and upwards, of land fit for cultivation. Each of these sizes is adapted to particular districts and other circumstances—especially to the degree of fertility and the amount of capital employed. It is a common but injurious mistake to suppose that the more land a farmer holds, the greater must be his profits. The profit does not arise from the land itself, but from the manner of using it; the best soil may be made unproductive by bad management, and the worst may be rendered profitable by an opposite course.

In Ayrshire, where dairy husbandry is well understood, and has arrived at greater perfection than in any other part of Scotland, the farms are of moderate size, being in general from 60 to 160 English acres. A farm of about 127 acres is reckoned a good size, and on this from ten to twelve cows are kept. Sir John Sinclair recommends that a clay-land farm should not exceed 380 English acres; and he justly remarks, 'that those who grasp at having farms of a greater extent, where servants are not immediately under the master's eye, lose rather than gain by extending their land. Where the soil is of a light description, a larger extent is necessary, as in such soils sheep and cattle are frequently fed in large numbers; and a farm of this description, of from 600 to 1000 Scotch acres, or 762 to 1270 English, is not considered too large. Where farms are almost entirely employed in pasturage, or in the breeding of sheep or cattle, as is usually the case in hilly districts, there can be no precise limits to their extent; some in the Highlands of Scotland, devoted to sheep-pasture, reach 25,000 English acres.'

The selection of a farm requires the whole ability and experience of the farmer. He must attend to all the advantages and disadvantages regarding it, so that he may fully make up his mind as to the amount of rent he considers it worth, taking care neither to be too cautious nor too rash. There is one common but very erroneous rule which guides the choice of a farm—namely, the success of the outgoing tenant. If he has made money in it, or is leaving it for a larger one, numbers will flock after it, and offer a high rent, without even inspecting it. But if the tenant be unsuccessful, all his misfortunes are attributed to the badness of the land, not to his own mismanagement; and few will be found willing to take the farm even at a reduced rent. These notions are very absurd; for the management of various farmers is so essentially different, that success or misfortune may be said to depend more on that than on either rent or quality of land.

The last advice which may be offered in reference to selecting and also managing land, is not heedlessly to carry prepossessions of what is right in one country to another country in which he may chance to settle. Every country, and indeed almost every district of a country, has its own peculiar fashions in agriculture as in everything else, and the meaning of these should always be carefully studied before pronouncing on their error or inutility.

Leases and Rents.

A farm is seldom conducted properly for the legitimate advantage of either landlord or tenant, except a lease of considerable duration be granted; for if the tenant be at all times liable to be dispossessed at the mere will of the proprietor, he can have no interest in improving the land, and therefore cannot afford to pay a sum suitable to the actual capabilities of the soil. According to the modern practice of agriculture, the profits of a farm are frequently prospective; a number of years must sometimes elapse before the ground repays the farmer for his sunk capital, and his trouble in effecting improvements. The duration of a lease consequently depends on the nature and condition of the soil, as well as some other minor circumstances. It is understood that a long lease is a much greater stimulus to spirited farming than a low rent. If the lease be long, and the rent high, great exertion is used by the farmer; but if the lease be long, and the rent low, a slovenly mode of farming, such as is found under the 'life-leases' of Ireland, may in general be expected. It appears, from all experience in Scotland, that a lease should neither be too long nor too short, but of a moderate duration, as nineteen or twenty years.

The connection between landlord and tenant is that of a disjunctive copartnery. The tenant trades upon a certain sunk capital of the landlord. The question, then, as to what is to be paid in the form of rent, is

[Continued on page 520.]

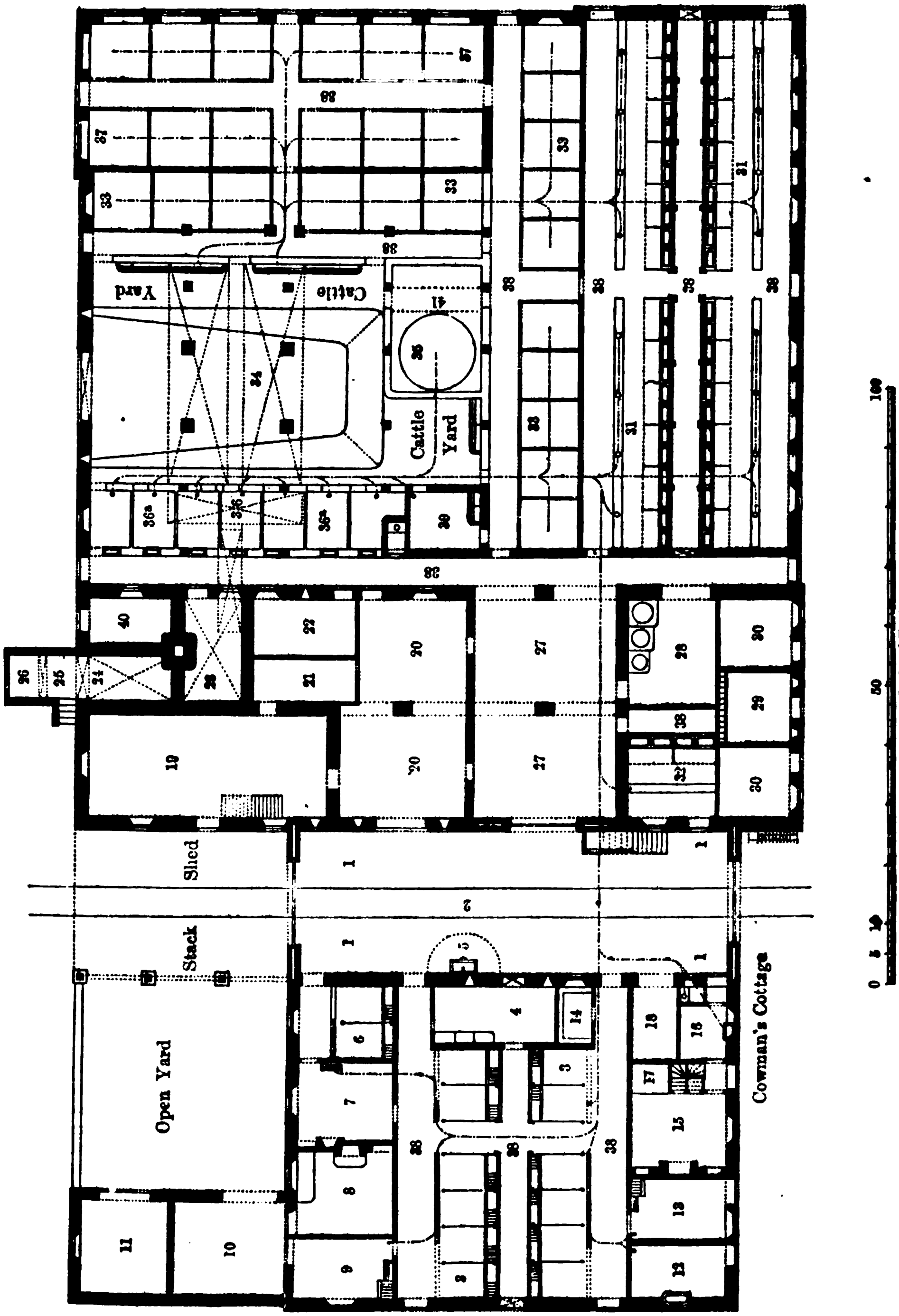


Fig. 24.—GROUND-PLAN OF MORTON'S MODEL COVERED FARM-STEADING.

1 is a covered yard or roofed court, extending from the front to the back of the building, including a stack-shed; and by means of a railway (2) running the entire length, and from one side of the farm to the other, the heavier cartages may be performed. For instance, stacks of grain, built on four-wheeled frames on the outskirts of the farm, may be conveyed at any time to the homestead, without being broken into cart-loads; and as the stack-house is alongside the thrashing-barn, the sheaves may be pitched at once from the rick to the feeding-board of the thrashing-machine. This covered court may also be used for storing temporarily unloaded grain, hay, &c.; and even should there be a scarcity of accommodation for fattening stock, a series of movable cattle-boxes may be placed in the centre division, and with the sliding-doors at both ends partially closed, the animals would be comfortably housed. It is intended, also, that this court should serve as a cart-shed, the carts being placed at the sides. At a height of ten feet, a projecting platform runs along each side, four feet wide, and railed in front, communicating between the various lofts and granaries, and for providing a suitable store-place for the lighter implements and tools not in constant use. A light drawbridge joins these platforms, over which cut straw or bruised grain may be conveyed from the barn-lofts to the horses' bins, and supplied through spouts in the floor above. The roof of this court is an iron girdered one, with a quantity of rough plate-glass in it.

3 is the work-horse stables, which may be entered either by the west side or by the covered court. Instead of facing a dead-wall, the animals stand in the reverse direction, and are fed through sliding sparred doors from the feeding-passage in front; this renders it more cheerful, and insures better ventilation, besides making the process of feeding more speedy. 4 is the hay-house; and in one corner are placed the corn-chests. 5 is a semicircular trough containing water for washing the horses' feet: it may be turned on when required, and deepens gradually to fifteen inches; and the waste water and dirt may be run off by a plug at the bottom. 6 is the riding-horse stable, fitted up in the same manner as that of the work-horses; 7, the harness-room, with the ploughmen's sleeping apartment overhead; and 8, the carpenter's shop; 9 is a loose box; 10, the implement-house; 11, for portable manures; 12, the bull's house; 13, the mare and foal's house; and 14, a dispensary, being all exceedingly useful departments, and scarcely to be dispensed with in a steading of this kind. 8 may be used simply for the lighter kinds of carpenter's or smith's work; but by fitting up, might be made into a regular workshop. The cowman's or grieve's cottage is so arranged that its occupant can get access to any part of the steading without having to go into the open air. Besides a living room, 15, scullery, 16, and bed, 17, on the ground-floor, two sleeping-apartments are provided above. Contiguous to this is the gig-house, 18.

19 represents the dressing-barn — the thrashing-barn and thrashing-machine being immediately above. As the straw leaves the machine, it is carried into the adjoining straw-house, 20, by an endless web. In connection with the thrashing-loft, is a sack-store with a lock and key, the whole enclosed with sparred wood-work. At the back of the barn, and connected with the thrashing-loft, is the chaff-house, 21, which may be entered from the straw-barn when the contents are required. Alongside this is the oil-cake bruising-house, 22, with necessary power from the engine-room behind. The engine-house, 23, though partly floored by the granary, is arched with brick, to prevent the risk of fire; and proper means are taken to carry off waste steam and obtain fresh air. The boiler, 24, is fired from the outside—a corrugated iron roof projecting over the firing-pit, 25, to protect the fireman in inclement weather; and beyond is an arched-over fuel-depôt, 26. Under the engine-house, a narrow arched vault, arranged at the end of the liquid tanks, is provided; and either here or in a corner of the engine-house, the liquid-manure force-pumps will be placed. 27 is the forage-house—a receptacle for turnips or any other food to be given to the cattle; and it and the straw-house are placed as nearly as possible in the centre of the homestead. Loaded carts can enter from the covered yard; and immediately adjoining is the boiling or steaming house, 28, where soft meat is prepared. The forage-house is lighted by borrowed lights from both ends, and by means of two strong plates of rough glass in the floor of the store-loft above. The granaries extend above the forage-house, half of the straw-barn, the chaff-house, and all the way to the gable at the engine-boiler. Part of this range may be set apart as an oil-cake store, and another portion as a site for the grain-bruisers. A stair in the covered yard gives easy access to the granaries on the one end, and at the other they communicate with the thrashing-barn by a side-door. 29 is intended for *web*-footed poultry; 30 are two infirmaries for sick animals, the doors of which open from the outside, so as more completely to isolate them from the cattle-houses; and above those are placed a poultry-room and dove-cot. It may be well to add, that the poultry-rooms can be heated by pipes from the boiling-house behind. On the west side of 30 is the hen trap-ladder. 31 represents the stalled-cattle houses; sliding sparred gates are fitted up, at which they are fed, and which insures better ventilation than if solid boarding were employed. The divisions should consist either of cast iron or flag-stone, or they may be formed of well-seasoned wood, impregnated with Boucherie's preservative material, or Bethell's creosote. 32, the dairy-byre, or cow-house, is fitted up in the same principle as the feeding-byre. Nos. 33 are intended to represent cattle-boxes; these are sunk nearly three feet below the level of the passages, to be gradually filled up as the manure is made; before each stall there is a gate from the passage, and the manure can be conveyed away by means of a barrow. It has been found upon farms where there is much straw to be converted into manure, that the system of feeding cattle in boxes with sunk floors has been attended by good results; there is, besides, less likelihood of bad odours arising. The cattle and manure yard, 34, is not meant to be a wet, irregularly spread dung-heap, which is to fill the whole steading with an unbearable stench; it is intended to serve as a large cattle-box, whereon is deposited the manure from the stalled house and stable, and all that is not washed into the tanks: this being bedded over with straw, and trodden down by the animals, will always be kept solid, and effluvia by that means avoided. But if there be not a good supply of straw, we would by no means commend the adoption of this department of a covered homestead. This yard is excavated to the depth of six feet, and slopes from the gateway towards the inner end. From the passage in front of the feeding-boxes, the animals in this court are fed, as merely a low stone-wall surrounds it. Under this court, as shewn by the dotted lines, lie the liquid-manure tanks. If the system of dissolving manure be practised, 35 shews where a pit may be sunk, the top of which should be covered with an iron grid. After the solid manure has been washed through the grid by water, the refuse is raked off into the dung-yard; and by means of a handle which opens a valve at the bottom of the pit, the mixture flows to the tanks; but if this system is to be dispensed with, a simple well will be sufficient to hold the drainings from the dung-heap and cattle-stalls. No. 36 shews where the gearing-pits range; this gearing, in connection with the engine, works the agitators in the liquid tanks, and space is left for a force-pump. Above this range, 36ᵃ, are placed the piggeries, each house provided with a swinging-door, at which to supply the food. Nos. 37 represent space for the accommodation of a hundred sheep, on sparred floors. The outside walls of this house may be of open brick-work, with slide-boards inside. The different pens are enclosed by light wood-work, with gates opening from the feeding-passage. Nos. 38 shew the leading passages of the steading: 39 is the calf-house, and 40 the tool-house.

determined by the value of this capital, and what return it will produce annually on an average of years. From this return the tenant is supposed to draw one share, while the other is handed to the proprietor of the ground. With respect to grazing-farms, they are let on the principle of how much stock they can regularly maintain; and not being liable to the same expenses for management, both landlord and tenant receive larger shares out of the gross product. In some instances, proprietors, from negligence or a wish to retain an undue power over their tenants, delay the renewal of the farmer's lease till the period is almost expired. This is highly injurious to both parties; as, while uncertain if he is to continue on the land, the tenant will naturally be slack in his exertions to improve it, or even to maintain it in a fair condition. This evil might be easily avoided, by the proprietor renewing the lease of his tenant a few years before the expiration of the time. When a landlord has an intelligent and industrious tenantry, with capital sufficient to cultivate their farms to advantage, he ought to be cautious of parting with them. Should the land have materially increased in value during the lease about to expire, it will be found most advantageous for the landlord to nominate a judicious valuator, and to offer the farm at the declared rental to the existing tenant, without bringing it to public competition.

In drawing up leases, it is customary to introduce clauses restricting the tenant to certain rotations of crops, manuring, &c., applicable to the few years which precede the termination of the contract. These clauses, and also others respecting the keeping of fences and roads in repair, are sufficient in all ordinary cases. Some landlords may be desirous of prescribing the exact mode of management of their farms; but this has a discouraging and injurious effect, and should therefore be avoided, except in what may be called improving leases, or engagements to improve the land in a certain manner. With regard to the form of a lease, it should commence, says Sir John Sinclair, 'with the necessary preamble, stating the parties contracting, the situation of the property to be leased, the extent of the farm—a plan of which ought to be subscribed by the contracting parties—the duration of the lease, and the time of entry: it is then proper to enumerate, 1*st*, The powers and privileges reserved to the landlord; 2*d*, The obligations incumbent on the tenant; and 3*d*, The stipulations obligatory upon both. Leases thus drawn up would not be liable to much uncertainty or dispute; and lest any should occur, it is expedient that a mutual obligation for settling by arbiters should be inserted.'

In modern farming, rent is altogether payable in money, or partly in money and partly in grain. The system of grain-rents is yearly extending in Scotland, and is highly popular with the tenants, as it equalises in a great measure the risk of bad seasons and low prices between farmer and landlord—not requiring from the former a fixed amount of rental from an uncertain and fluctuating source. Thus, for example, a farm at the nominal rental of £500 a year would be let for £250 or £300 in money, the remainder being payable in so many quarters of wheat, barley, and oats, at the fiars' prices* of the county. When the rental is estimated at so many quarters of these grains, the average of the three is taken, under the title of the *Triple Quarter;* but frequently wheat alone is taken as the convertible grain, and then, as the case may be, nine or ten bushels are given per acre. In order still more to equalise the fluctuations in price—that is, to prevent the rents from rising too high in scarce years, and falling too low in plentiful harvests—it is becoming usual to fix a maximum and minimum price, at which the grain shall be convertible into money when the fiars' prices exceed or fall below them. Thus, if the maximum for wheat be fixed at £3, 16s., and the minimum at £2, 10s., it will prevent a ten-bushel rent from falling below £3, 2s. 6d., or rising above £4, 7s. 6d. per acre.

The periods of the year, at which tenants remove from and enter farms, are very various. In many parts of England, Michaelmas, or 29th of September, is the period for both grazing and arable farms, that being the most suitable on account of the number of great stock-fairs held at that time, and other circumstances. In Scotland, Martinmas, or 11th of November, is the usual period. It is considered to be a most advantageous rule, that in all cases the removal of an outgoing tenant should be entire, not partial, as bit-by-bit removals too often lead to disputes between the retiring and entering individuals.

Arrangement and Management.

With respect to the arrangement and management of a farm, we cannot do better than extract the excellent digest of rules from the *Code of Agriculture:*

'1. The farmer ought to rise early, and see that others do so. In the winter-season, breakfast should be taken by candle-light, for by this means an hour is gained, which many farmers indolently lose, though six hours so lost are nearly equal to the working-part of a winter-day. This is a material object where a number of servants are employed. It is also particularly necessary for farmers to insist on the punctual performance of their orders.

'2. The whole farm should be regularly inspected, and not only every field examined, but every beast seen at least once a day, either by the occupier himself or by some intelligent servant.

'3. In a considerable farm, it is of the utmost consequence to have servants specially appropriated for each of the most important departments of labour; for there is often a great loss of time where persons are frequently changing their employments.

'4. To arrange the operation of ploughing, according to the soils cultivated, is an object of essential importance. On many farms there are fields which are soon rendered unfit to be ploughed, either by much rain or severe drought. In such cases, the prudent farmer, before the wet season commences, should plough such land as is in the greatest danger of being injured by too much wet; and before the dry period of the year sets in, he should till such land as is in the greatest danger of being rendered unfit for ploughing by too much drought. The season between seed-time and winter may be well occupied in ploughing heavy soils, intended to be laid down with beans, oats, barley, and other spring-crops, by means of the scarifier. On farms where these rules are attended to, there is always some land in a proper condition to be ploughed.

'5. Every means should be thought of to diminish labour, or to increase its power. For instance, by proper arrangement, five horses may perform as much labour as six, according to the usual mode of employing them. One horse may be employed in carting turnips during winter, or in other necessary farm-work at other seasons, without the necessity of reducing the number of ploughs. When driving dung from the farm-yard, three carts may be used—one always filling in the yard, another going to the field, and a third returning. By extending the same management to other farm-operations, a considerable saving of labour may be effected.'

To this digest it may be added, that the farmer should habituate himself to keep regular accounts of his affairs, which may be done by means of a cash-book for all outlays and receipts as they take place; a labour-book, in which to mark the commencement and time of work of every individual employed; a journal for

* Fiars' prices in Scotland are the average prices for each county, as fixed by the sheriff with a jury, upon the evidence of the principal buyers of grain within the district. The average is usually struck about the beginning of March for the crop of the preceding year.

entering daily transactions and memorandums; and a ledger, in which a special debtor-and-creditor account is kept of every department, as well as a general account of the whole concern.

WASTE LANDS.

According to the agricultural statistics which we now possess of Scotland and Ireland, and of one-fifth of England and Wales, taken in eleven sample counties, it appears that out of the 74,000,000 acres in the United Kingdom, only 42,000,000 are in cultivated arable and pasture, the remaining 32,000,000 being thus distributed:

	Acres.
Woods and plantations, ...	2,000,000
Sheep-walk (Scotland), ...	7,000,000
Unenclosed pasture (Ireland), . . .	8,000,000
Mountain, peat, and flat red bog (Ireland),	3,000,000
Other waste—say, ...	12,000,000

Much of this large proportion of our territory is either situated at such an altitude, or else so naturally barren, as to be hopelessly beyond the reach of improvement; but estimating from Mr Couling's valuation in the year 1827, and the amount of land enclosed since that time, we have now about 16,000,000 acres capable of being added to the arable and pasture of the kingdom.

Considerable misapprehension exists as to the character and capabilities of these cultivable waste lands, and we have no reliable authority furnishing us with exact information; however, there is sufficient evidence to shew that they generally consist of the naturally poorest or most unfavourably situated ground, or such as is least remunerative to the husbandman, owing to the heavy outlay required for its reclamation.

From the great decrease of enclosures, during the present century, in spite of the vast and rapidly accelerating increase of population and demand for food, it is plain that but little ground yet remains waste which it would be worth while to cultivate, under our present system of tenancy and our present order of agriculture; unless, indeed, it can be shewn that there exist any wild tracts of rich soil, that are locked out of reach of the free investment of capital and industry, only by some defective legislation, some anti-social privilege, or unrighteous ownership. Here and there, it is true, are patches of land upon which legal or personal considerations forbid the eager cultivator to enter; such, for instance, as Pill Moor, in the North Riding of Yorkshire; and again, Cannock-chase, in Staffordshire, the property of the Marquis of Anglesea—14,000 acres in a populous district, and one-half capable of profitable cultivation, being chiefly dry turnip-land on red sandstone. And in the Scotch Highlands, we hear much of honest industry in sheep-farming being interdicted on a large scale, for the mere sake of creating sport for the deer-stalker. But nowhere do we find tracts of dense weald and tangled copse, such as once overspread the fertile clays we are now draining and grain-cropping; in few places are there districts of wild heath and wold precisely such as have been converted into turnip and barley farms; and still more rarely are there wide fens and marshlands lying unembanked and unreclaimed. There are parks which might be brought into tillage, forests that might be cleared, sandy wastes that might be planted, bogs which might be drained, sheep-walks capable of improvement, and salt-marshes needing enclosure from the ocean; but all, generally speaking, at an expense which renders the propriety of the attempt somewhat questionable. The notion, then, that there exist wide-spread tracts of good land, unprofitably waiting till their owners permit them to be tilled, is not correct; there are but few plots capable of ordinary culture which are not already brought under the plough, or appropriated to the pasturage of cattle. British agriculture has arrived at that point of its history in which the problem is, how to increase the yield from each acre, rather than where to extend the area operated upon. And when we remember that, of the 23,000,000 acres of wet land cultivated, or capable of cultivation in Great Britain, less than 2,000,000 only are permanently drained; when we consider how far behind the two or three best counties is the agricultural management of the rest of the kingdom; and how small a proportion of the estates, even in the first-class localities, are farmed in the highest manner, we can easily see that, by a simple extension of the best husbandry, and the application of more capital and intelligence over the surface already in cultivation, the produce of the United Kingdom might be doubled, or, at anyrate, prodigiously augmented, without our having recourse to the costly reclamation of waste lands. Still, so long as the system under which land is occupied continues to trammel enterprise and improvement, and so long as science and practical skill are so partially diffused among farmers, the waste lands will be resorted to by bold proprietors and venturesome tenants; and that instinctive preference felt by the great majority of men for agricultural before all other pursuits, will not fail to lead strong-armed labourers and town-wearied mechanics to push stone-walled enclosures up the steep sides of moors and fells, to creep with gardens and green crops up the sandy heaths, to tap dropsical mosses, and bale out the tide from fat marshes.

The question as to the propriety of reclaiming a really improvable waste is, in any particular case, to be satisfactorily answered by ascertaining at what expense, in relation to the probable profit, the process may be performed. A barren rocky desert may be rendered productive by covering it with soil and manures brought from a distance of miles, aided by years of skilful tillage; but will the returns in produce be an equivalent for the excessive outlay? Gold itself may be purchased at too high a price, and so may agricultural improvements. In all projected undertakings of land-reclamation, whether by capitalists or by those who propose to expend only time and personal labour, it is necessary to calculate what will be the probable return, within a moderate length of time, for the outlay—always keeping in view the prospective prices of produce during the period.

We will now proceed to describe the nature of the various waste lands, the best means to be adopted in reclaiming them, and the results which may be expected to reward the enterprising improver.

MOORLANDS, HEATHS, DOWNS, AND HILLY WASTES.

Our principal English *moors*, as distinguished from the fells and actual mountains, are in the counties of Northumberland, Durham, Cumberland, Lancaster, York, Stafford, Chester, Derby, Devon, Cornwall, Somerset, &c.

The Yorkshire moors are the most extensive and important in England. The eastern portion, principally in the North Riding, rise about 1000 feet above the sea. The surface of some of the hills is entirely covered with large freestones; and in other places mosses, sometimes very large; the prevailing soil being peat-earth, which is generally covered with heath. On that portion called Hambleton Hills, the soil is much better, being good loam on a limestone rock. The climate is dry, but cold and backward; however, portions of these lofty and exposed regions have been brought into tillage; and sheep are being fed on what used to be the haunt of the wild mouse and the mole, and luxuriant oats wave before the wind that used to whistle through the whins and the heather.

The western moorlands, almost equally divided between the North and West Ridings, are of very great extent, but not generally so sterile as the eastern. Many

of the hills are covered with fine sweet grass; while in other places there are large tracts of heather mingled with grass, bent, or rushes. On these waste lands of the millstone-grit formation, the productiveness of many enclosures shews what a large extent yet unreclaimed is capable of. There are many instances of this high ground growing nothing but heather, and not realising more than about 1s. 6d. per acre, shooting included; whilst immediately adjoining, on the same level, are cultivated plots letting for 20s., 25s., and up to 30s. per acre, and producing excellent crops. There being no very great proportion of peat on these lands, their reclamation would be the sooner accomplished.

The Derbyshire Peak is very wild and barren, not so much from its altitude as from the steep, rugged, and nearly soilless sides and crags of the limestone and the millstone grit, and from its bogs and moorlands covered with heath and boulder-stones of every size; while the streams carry down the waste of crumbling grits and shales in their peaty, brackish waters, to enrich the meadows and vales below. The soils on the grit are chiefly of a sandy kind; the great difficulty in cultivating being the first clearance or removal of the rocks and blocks everywhere scattered over the surface. Vast tracts have been cleared and taken in; and Mr Rowley gives, in the *Royal Agricultural Society's Journal*, the following account of the method of encroaching upon the moor: 'Stanton House, the farm of W. P. Thornhill, Esq., is 715 feet above the sea-level. A great part of the estate has lately been taken from the waste at an average cost of £15 per acre, one portion having cost £50 an acre in stubbing, ridding, and blowing up grit-rock. The first process was the draining at eighteen or twenty inches deep, six and seven yards apart. This was found insufficient; and deeper drains, from three to four feet, put in, and a perfect though expensive drainage completed. The rotation of cropping followed is the four-course: the turnips are grown with bones and guano, and a heavy dressing of farm-yard manure; and the bulk of them are consumed on the land by Leicester and Shropshire-down sheep. The average produce of oats is seven quarters, and of wheat, four and a half quarters, per acre, of excellent quality. Favoured by a southern aspect, and sheltered from the north and westerly winds by extensive plantations of larch and spruce, the farming at this elevation is under advantageous circumstances, and very different to that on the opposite hills facing the north and east. At this elevation, in no part of the midland counties has autumn-wheat been successfully grown; while in the mountains, wheat is never attempted at elevations from 100 to 200 feet lower.'

Cornwall contains about 200,000 acres of waste, the greater part being held in common by surrounding farmers. To shew what skill, enterprise, and capital will do on some of the most exposed parts of the granite wastes, Mr Karkeek says, in the *Royal Agricultural Society's Journal:* 'Let the reader imagine a piece of waste strewed over with granite blocks, some of immense size, with heath and furze shooting up in the interstices, at an elevation of 600 feet above the sea-level; and notwithstanding these natural obstacles, I witnessed a short time since, on an estate of only 150 acres—not many years since reclaimed from the Sancreed wastes—130 head of cattle, Devons and short-horns, 100 pigs, and 35 horses and colts. The average produce is from 45 to 60 bushels of oats, from 18 to 21 of wheat—not much grown—300 bushels of potatoes, and from 18 to 25 tons of turnips. It frequently happens that the first crop of potatoes raised on this reclaimed land will more than repay the expenses.' And again: 'The Messrs S. & R. Davey, of Redruth, have broken up about 100 acres of thin rocky soil on the slate-formation, at a cost of enclosing and cultivating—including the expense of the first crop—varying from £10 to £11 per acre. At the commencement of their undertaking, the land was manured with bone-dust and lime for wheat; but the produce was only fit for pigs and poultry. The present method of cropping is Swedes or turnips eaten off, followed by oats and grass and clover seeds. The crops will average from 60 to 70 bushels of oats, and from 18 to 25 tons of Swedes per acre. This has been effected entirely by the use of bones and guano. It has been correctly ascertained, that in the parishes of Perranzabuloe and St Agnes, there are 7037 acres of the same kind of waste, 5000 of which would pay handsomely for reclaiming.'

In North Wales, there exist extensive tracts of waste upon the mountain-sides capable of cultivation. On the Hiraethog range, the luxuriant growth of the heath, fern, and foxglove in many places, is a clear indication of the riches that are in store for the first adventurer who may attempt to break up the almost desert waste; and many patches of deep hazel loam are seen, which have been lately reclaimed from the wild state, now covered with oats and grass of the best description. There are wide-spread tracts of land in Merioneth and Montgomery-shires, which, by paring and burning, draining and liming, would produce excellent crops of turnips and rape—enabling the farmer to maintain as large a flock of sheep in winter as in summer, instead of being compelled to draft them off to lowland graziers, as at present. Before such heath or bog land can be profitably cultivated, it is indispensable to apply lime; and the question, therefore, of future improvement is in a great measure dependent upon the facility with which this substance is procurable.

We may here speak of the processes of Burning and of Liming.

Paring and Burning.—Suppose the plot to be reclaimed has been surrounded by a substantial stone-wall or other fence, dried by stone or tile drains if necessary, and all stones that are visible upon the land grubbed up and carted or conveyed off upon sledges. The paring is to be done, if possible, in the months of April and May, in order to have the most favourable part of the year for drying the parings well before burning. Several paring-ploughs are manufactured; but the best method is to employ the *breast-plough* or *paring-spade*, the surface being so irregular, and very thin slices being required. The parings should be burnt directly they are sufficiently dry, as, after lying a month or six weeks, they begin to unite with the ground, and imbibe moisture from the young grass vegetating beneath them. Sometimes they can be burnt as they lie, without being collected into heaps; and in this way, the fire, in consuming the lingy side, which is undermost, chars the surface of the soil at the same time. If burnt in heaps, these should be very small, in order to secure a good black ash instead of the hard lumps of red ash produced by large fires. The art in burning is to keep a smouldering fire, never smothering it with too much earth, and keeping the outside layer of sods so close as to prevent the fire from kindling into flame. The ashes should be spread, care being taken to clear the bottoms of the heaps well out, so that the first crop may be free from patches. The cost of thus paring, burning, and spreading is about £1 per acre. The ashes require to be well ploughed in.

Liming.—When the land has been well ploughed and reduced by harrowing, the lime, having been laid for some time in large heaps, and properly slaked or brought into a powdery state, should be placed in small heaps—say one to every square perch—then carefully spread over the surface, and well harrowed in. The quantity may vary from 100 to 200 or 250 bushels per acre, according to the nature of the soil. Strong soils, of a sour or rushy nature, containing much fibrous and inert vegetable substance, require more than those of a lighter description. Lime is invaluable as a first dressing in reclaiming heath-land. It acts as a powerful stimulant upon inert fertile ingredients in the soil,

and decomposes and corrects the crude and acrid matter arising from the decay of organic bodies in virgin soils. It is able totally to eradicate the heather, alter the texture of the land, and produce a rich and sweet herbage. In the application of lime in reclaiming moorlands, it is a rule always to give abundance, and in a newly slaked condition, in order that it may have its full effect. If slaked a considerable length of time before it is applied, it does not act so powerfully either in reducing the natural herbage or neutralising the acids, as when used in a hot powdery state.

Not only for tillage, but also for improving the pasturage of the waste lands when laid on as a top-dressing—that is, thinly powdered over the surface—lime is found to have very extraordinary effects; and it is satisfactorily proved by experience that the proprietors of waste moorlands within reach of lime have only themselves to blame for their grounds continuing in sterility. Were proper arrangements entered into between the landlords and the tenants, a great proportion of the high pastoral grounds now lying in a profitless condition, might be progressively improved by simply draining where needful, and top-dressing with lime.

Devonshire comprises about 455,000 acres of waste land, much of which may be rendered productive. Dartmoor—no less than 250,000 acres uncultivated—has principally a peaty soil, which during the summer months is dry and firm; in other parts, as in Dartmoor Forest (80,000 acres), there exists a perfect swamp even in summer. The mean elevation of the district is nearly 1800 feet above the level of the sea; the climate cold throughout the greater part of the year, and materially impeding vegetation. Undoubtedly, the main cause of this unfavourable climate is the want of drainage; and it is nearly useless for private individuals to attempt isolated enclosures until all the district has been drained by a simultaneous and united undertaking.

The enclosure of Exmoor Forest, in Somersetshire—20,000 acres, at an altitude of 1000 to 1200 feet—is one of the most striking examples of the improvement of waste land. The surface is in the form of an undulating table-land, furrowed by deep stream-valleys, and covered over almost its whole extent with a moist pasture. There is considerable depth of soil on the boggy portions, which, when drained and limed, make good land; some of the peaty lands rest on a crust or pan, which must be broken through by subsoiling; while other parts have a dry soil, needing only to be pared, burnt, and limed, in order to bear fine root-crops. Rain and mists, and Atlantic gales, are the principal opponents of the cultivator; but plantations and good hedges are rising to afford the requisite shelter. The best fence for this purpose consists of a bank of earth, supported on both sides by stone-walling, five or six feet high, and six feet thick at bottom; and on the top of this, beech-trees are planted, and found to grow well. Mr Knight, the proprietor, has erected a large number of farmhouses and cottages, and constructed nearly 30 miles of road, and 150 miles of wall or bank-fencing; and a large portion having been pared, and burned, and limed, is now growing roots and grass, and indeed oats also with great success. One of the most remarkable features of the Exmoor improvements consists in the control of the water. Instead of the drenching rains being suffered to wash away fine particles of soil, manure, lime, or ash down the hillsides, the water is caught in carrier-canals and reservoirs, conducted along the sides of the declivities, and made to trickle down over water-meadows, or, with soil in suspension, allowed to rush over the surface where wanted, or else employed to turn mill-wheels and machinery at the farm-steads.

This leads us to notice very briefly the subject of *Irrigation.*—The object to be obtained is to flood the land at pleasure in such a manner as to maintain an incessant shallow flow or trickling amongst the blades of herbage. To give the surface the requisite inclination in every part, to design and lay out the *carriers* which bring the water, and the intervening drains which convey away the spent floods, according to the levels of the land, and have the water under perfect command, requires very considerable knowledge and judgment. The water is to run in the months of October, November, December, and January, from fifteen to twenty days at a time, with intervals of five or six days for the ground to dry and air. The question as to what water is suited or not for the purpose, is also one of some difficulty.

The Duke of Portland's water-meadows at Clipstone Park, in Nottinghamshire, are the most famous in England: many miles of a swampy valley, thick set with hassocks and rushes, the favourite haunt of wild-ducks and snipes; hillsides covered with gorse and heather; and a rabbit-warren, over which a few poor sheep wandered, having been changed into a succession of the richest meadows, producing a marvellous quantity of green cuttings and pasturage.

The Scottish moors are too frequent and extensive to be particularised. The moor of Rannoch, in the neighbourhood of Ben Nevis, includes a vast tract of rocks, lakes, and morasses, elevated about 1000 feet above the level of the sea, and is one of the most dreary, wild, and worthless districts imaginable. It is not inhabited, and seldom even visited. There is a somewhat similar district on the west coast of Cromarty and Sutherland; though without any great hills, and not very elevated, it is extremely rugged, bleak, and miserable. The soil of most of the Scotch moors, as well as of many of the mountains, is peat. On the granite formation, the soil is thin and poor, and situated in a cold bleak climate. It is of no agricultural value, so far as the production of corn and roots is concerned, and is covered with heather and coarse grass. On the whinstone or trap hills, the soil is of a very light character, and was first improved by the introduction of bone-manure, so that now oats and turnips are grown nearly 1000 feet above the level of the sea. In the Highlands, prodigious improvements have been made by clearing moors of stones, burning heather, extensive planting, draining mosses by open ditches, collecting and distributing the water along the hills by means of artificial canals; and improving the natural grass growing upon a thin soil, by draining and by grazing with sheep.

The most extensive of the *heaths and sands* of England are those of Surrey, Dorset, Hants, and some other counties, as Norfolk and Suffolk. The heaths of Surrey, particularly that of Bagshot, consist of a sterile and apparently unimprovable sand, for the most part level, but elevated between 400 and 500 feet above the sea. Only a few patches of good loam are to be found; so that the district will probably remain worthless, in an agricultural point of view, and its products be confined to a growth of heath, gorse, fern, and to a few plantations of larch and Scotch fir. 'On Bradley Common,' says Mr Evershed (*Royal Agricultural Society's Journal*), 'an extent of more than 100 acres is being reclaimed at an expense of £7 or £8 per acre; but it appears doubtful if the larch and fir which have been planted will thrive. The process of breaking up the ground consists in paring, burning the heath, and trenching, by spade and pick, to the depth of twenty inches, or more, according to circumstances. This depth is generally sufficient to break through the "iron crust," which is invariably found below the surface of the sand, and which, being impervious to water, is the cause of the heath's being frequently wet and boggy.'

The heaths in Dorsetshire and Hampshire are very extensive. In the former county, plots of twenty or thirty acres are taken at nominal rents by small farmers

for reclamation. Mr Ruegg (*Royal Agricultural Journal*) says: 'The land is broken up with large mattocks, at a cost of £2 per acre; the surface is either burnt or worked about until the turf decomposes. The next process, chalking, is very expensive; as they go from three to five miles for the chalk, and though it costs at the pit only 6d. a ton, its cost on the land is £3 an acre. It might pay to sink a shaft, as they do in Hampshire. The general dressing is twenty tons an acre; but on sandy soil this is thought too much. It is worked down with Crosskill's clod-crusher, and scarified, and sown with turnips or rape. It is well dunged, and two or three good crops are taken from it, but at a heavy cost. The green crop is eaten off, and very large crops of oats obtained—as many as sixty or seventy bushels per acre.'

The chalk *Downs* of our southern counties remain to be noticed—including Salisbury Plain, in Wiltshire—an elevated table-land, with a thin, light, and flinty soil, covered by a fine greensward. In Dorsetshire, a very great extent is being broken up every year; and land but lately the habitation of foxes and rabbits, producing furze, fern, and a scanty portion of sheep-feed, with a return of only 2s. 6d. an acre, is now yielding £1. Breast-ploughing and burning the turf is the first operation; and after a crop of rape, wheat, and clover has been taken, the land receives an application of chalk.

Although it might not pay the farmer to break up very lofty, steep downs, having scarcely any soil, still thousands of acres in Sussex, Wilts, and other counties, now depastured by flocks of sheep folded on arable land at night, and extensive tracts, producing little but heath and furze, might be brought into profitable tillage, and made to yield in saintfoin, clover, and other artificial grasses, an amount of food immensely greater than that afforded by the natural herbage. Many trials have been commenced, and afterwards abandoned, by those who neglected the principle that the soil has to be made, and enriched by manures and green crops fed off with sheep, instead of immediately taxed with corn cropping; whereas, there are innumerable instances to shew that light chalk-lands, as well as other wastes, will prove worth reclaiming, if only persevered with: tillage and the application of mineral and animal manures, for a course of years, having the effect of creating a good soil where scarcely any existed before.

The basis of improvement in light, silicious soils, is the application of chalk, marl, or clay; this admixture giving greater solidity and retentiveness for moisture, a power to arrest and retain organic riches from the atmosphere, while supplying many mineral substances required in the constitution of a fertile soil.

Marling and Chalking.—*Marl* is a term applied in different localities to a variety of earths, generally consisting of a mixture of clay, sand, and lime, but also including such substances as red or blue clay of an unctuous or pulverulent character. Marl-beds are found in hollows at the foot of hills, at the bottom of ancient lakes, below peat-mosses; particularly in districts where chalk-hills, limestone rocks, or spring-waters containing much lime in solution, abound. *Clay-marl*, used in Norfolk and Suffolk, is the *till* of the diluvial or drift deposits, consisting of blue and yellow clay containing lumps of chalk. A common dressing upon gravelly or sandy land is from forty to seventy cubic yards per acre. The cost of filling and spreading is about 3d. per yard; and of the cartage, according to the distance. *Shell-marl* is a kind found under bogs and mosses, and at the bottom of most dried-up lakes, and is evidently a calcareous earth, formed of decomposed testaceous fish.

Chalk is employed as a manure and mechanical solidifier of light soils, in every locality where it exists, and has been the chief agent in improving the thin, flinty loam of the Lincolnshire wolds. It is there excavated from pits or quarries, and carted upon the land at an expense of 5d. or 6d. per cubic yard. A dressing of 80 to 100 cubic yards is applied per acre; the chalk is weathered by exposure to a winter's frost, and then crumbled down by harrowing. On the Chiltern Hills of Buckinghamshire, pits or wells are sunk in the fields, about twenty feet deep, and the chalk drawn up in baskets by a wheel. A load of sixteen bushels costs 5d. for digging, drawing, and barrowing out; 3s. per 100 loads is charged for spreading, and 4s. per 100 loads for levelling-in the pits.

MOSS-LANDS, FENS, AND MARSHES.

Peat-mosses are supposed in some cases to have been occasioned by the destruction of ancient forests, either by the hatchet or from natural decay. In other cases, bogs have been formed by aquatic plants vegetating in hollows, holding water; mud accumulating round their roots and stalks, formed a semi-fluid mass, which increasing gradually, filled up the hollows, so that sphagnum and other mosses could grow. The peat which has been formed in this manner is therefore a compound of vegetable substance not entirely decomposed; commonly enclosing decayed trees, of pine, birch, hazel, or oak. The lowest layers of peat are commonly formed of aquatic plants; the next, of mosses; and the highest, of heath. The quality of the bog may be judged of from the plants which grow upon it: on ground completely saturated with water, various species of moss grow, to the total exclusion of other plants; but if the land should in any way become drier, reeds, rushes, and other plants spring up in the place of the moss; and all the moss-tribe, the horsetail and the marsh trefoil, are fibrous, and difficult to decompose; while reeds, rushes, and sedge are comparatively easy of decomposition.

Morasses abound in all mountain and moorland districts, particularly in Scotland; while extensive tracts of flat mosses and peaty land are found in Lancashire, the fen-country of Cambridgeshire and Lincolnshire, and in Somersetshire. In Ireland, the mountain peat occupies 1,300,000 acres, and the flat or red bog, 1,600,000 acres, including the extensive tract, known as the Bog of Allen.

The following are examples of successful undertakings upon various descriptions both of the flat or red bog and the black or hill peat.

The reclamation of a large portion of Chat-moss, in Lancashire, was commenced by Mr Roscoe of Liverpool, and has been subsequently prosecuted with success. Drainage—the first step to improvement—was effected by cutting open parallel ditches 66 yards apart, 4 feet wide at the top, and sloping down to about 14 inches at the bottom, 3 feet 6 inches deep. In a wet floating mass like this moss, it was not possible to sink the ditch to the whole depth at once; and the first two spits being taken out, it was then left for time to consolidate the surface. The covered cross-drains, 10 yards apart, laid 3 feet deep, and running into the open ditches, were commenced; but in forming these, as well as the open drains, it was necessary to allow some time to elapse between the different operations, that the water might to some extent run off; the hollow drains being made by the top sod, dried by exposure to the air, being wedged into the open cut, and the peat thrown in again upon that to fill up. When the surface was partially dried, the heath and other plants growing upon it were set on fire, and burned off as closely as possible; and by ploughing and cross-ploughing, and cutting up the sods by a roller armed with knives, the tough and elastic character of the surface was destroyed. Both men and horses were obliged to work with pattens or flat pieces of wood attached to their feet. After this process, marl—found at the southern edge of the moss—was laid on the top, by means of a movable railway; the dressing being 100 cubic yards to the acre—equal to about one inch covering over the whole surface—and the average distance which the marl had to be removed,

about two-thirds of a mile. Town-manure was brought by the Liverpool and Manchester Railway—a mixture of night-soil and ashes being preferable to anything else; and by growing a crop of potatoes in the first instance, the different particles of moss-earth and manure became so thoroughly blended together that the soil formed would produce anything, and wheat, clover, and oats followed each other in successful rotation. After-experience has shewn that turnips, oats, and potatoes are the best crops for such land; and an admixture of lime and salt answers better than the bulky marl for destroying the vegetable fibre, converting the moss into friable mould, and preparing it for a first crop of potatoes. On the extensive mosses in the Fylde district of the same county, oats and potatoes, turnips, and even wheat, may be seen growing on the surface of bog perhaps thirty feet or more in depth; and, indeed, to cultivate a bog is a much less difficult task than to improve a moor; because the peat is only an excess of manure more readily destroyed than created. Main drains are first made conformably to the extent, configuration, and situation of the moss, to the levels of surrounding lands, and to the levels of the substratum on which the moss rests. Roads are formed by first cutting open drains on each side, and throwing the material into the centre of the intended roadway; and when this is tolerably dry, sand or gravel is laid on several inches thick, and four yards wide. Open ditches are made, dividing the land into fields of about four acres each, and covered drains are laid at ten-yard intervals. These are wedge-drains, similar to those of Chat-moss, and are three feet deep. The whole expense of draining each field of four acres amounts to about £1, 6s., to which must be added a share of the outlay for the general main drain or canal, and for roads. Marl to the extent of 100 or 110 tons per acre, is then applied by a portable railway, at a further expense of about £1, 14s. per acre. The value of the land thus reclaimed is often more than £1 per acre to rent, and is calculated to pay more than 10 per cent. on the outlay.

Some of the most unpromising bogs in Ireland have been converted into fertile soil, most commonly at an expense of about £15 per acre; though some have cost nearly double, and others, again, only £8 or £10—so much depending upon local circumstances, facilities for discharging the drain-water, and the distance of the marl, or other solidifying material, or the lime, which is so efficacious in altering their qualities. Black or mountain peat is generally situated favourably for drainage; and if marl, sand, or clay is not obtainable, and even lime cannot be procured, paring, and burning, and manuring will be found to produce, in time, a soil capable of bearing good crops; and this is the case even at very great altitudes, provided the reclaimer be content with rape or hardy turnips and grass-seeds for sheep-feeding, instead of trying to grow corn.

We have not space to describe the great drainages of our fens by embanking rivers, excavating straight instead of circuitous channels, lifting up the drain-waters from the low-lying lands by wind-mills and steam-engines, enclosing the muddy sands of estuaries and salt-marshes along the coasts from the sedimentary tides, and issuing the drain-water through sluices with self-acting valve-doors to keep out the sea. Tracts of open marsh deposited by the ocean still exist on the English coast, which it might be worth while to embank; in Ireland, there are some very fine *slobs*, as they are there called; and in South Wales, there are 11,000 acres of fen and marsh land, which, if drained, could be made into very excellent soil. We must allude, however, to a method of improving low flat land lying contiguous to tidal rivers or estuaries, and below the level of the tides at high-water—called

Warping.—The waters of the Ouse, Trent, and other tidal rivers converging to the Humber, hold in suspension a large amount of earthy sediment, locally termed *warp*, and by being conducted over the land, and allowed to deposit their slime, have covered some 20,000 acres of worthless peat-moor and weak sand with the richest possible soil. A sluice with opening doors is erected in the bank of the stream, a main-drain cut and embanked across the low lands to the ground intended to be warped; and the latter is surrounded with a well-sloped bank, sufficiently high to hold the water. The 'compartment' may be fifty acres or less—being so much as the farmer can conveniently spare at one time. The thick water enters the enclosure at the furthest side, and directly it expands into a quieter current, begins to let fall the deposit, passing slowly over the surface of the land on its way to the near side of the compartment, where a tunnel permits its escape back again into the drain at ebb-tide. The further side having received a sufficient coating, *inlets* are cut in the bank of the drain at a less-advanced position, until the water gradually silts up the entire enclosure. From one to three feet thickness of deposit is obtained in from one to two and a half years, according to circumstances; the expense, with large drains, and other works included, ranging from £12 to £20 per acre; while on land adjoining the public warping-drains, it is much less than half that sum. When the new warp has become partially solidified, furrows are dug in it; and after being exposed to a winter's frost, seeds are sown, with oats to shelter them. These are grazed with sheep for two years, when the excess of salt having drained out of the soil, beans, wheat, potatoes, and flax follow. This alluvial soil, rich in organic matter, is most prolific—worth £60 to £100 per acre—and commanding a rental of £2, 10s. or £3, or even much more.

The same kind of silt or warp is sometimes excavated from old river-channels, and by means of a movable railway, spread upon the boggy land to be improved.

In the Cambridgeshire and other fens, the peaty soil is improved by

Claying.—Pits are sunk in rows, say fourteen or fifteen yards apart; and on reaching the blue calcareous and greasy clay, at a depth of two to six or more feet, the workman casts out some two to four *draws*, throwing part on each side: the black soil removed in sinking the next adjoining pit is thrown into the last to fill it up; and so on, across the field. The object in sinking pits is to prevent the sides from coming together, which would be the case if a long open trench were dug.

CLAYS AND OTHER WET LANDS.

Our subject does not include the general agricultural improvement, by under-draining and other means, of ground already in cultivation; but there exist, scattered throughout the kingdom, so many tracts of almost profitless heavy land, whether in common or enclosed, that we must say a word as to the best methods of rendering them serviceable. Clays are inherently fertile, but mechanically difficult to manage: deep and effective drainage, deep tillage, a thorough exposure of the pulverised soil to atmospheric enrichment, and manuring with green crops ploughed in, in most cases liming, and in many burning the clay, are the principal features of heavy-land amelioration. Mr Smith of Deanston taught us to break up the subsoil, in order to deepen the staple gradually, to open a passage for the descent of water, air, and the roots of our cropping, to render the land drier, warmer, and more suitable for vegetation. But as there was a prejudice against bringing up a bad subsoil to damage the upper cultivated stratum, only a stirring and crumbling share was used—as it were, a horse-pick breaking up without raising the under stratum. Now, however, it is proved that we may trench—that is, raise the under-soil into perpetual exposure upon the surface, with the best possible results. The Marquis of Tweeddale's experience at Yester in East Lothian is very remarkable on this

point. The form of the share of his subsoil trench-plough to follow in the furrow made by the common plough, is shewn in the following cut. Fig. 25 is a plan,

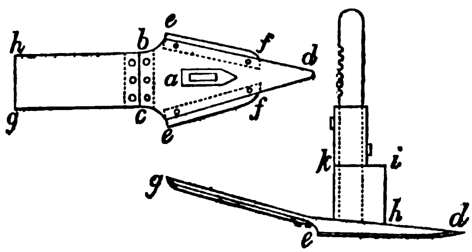


Fig. 25. Fig. 26.

and fig. 26 an elevation; *a* is the place of insertion of the coulter or stem. The sock, or share, is twenty-four inches long from *d* to *bc*, and fourteen inches wide. Two steel cutters, *ef*, *ef*, are fixed on each edge; and a tail-piece, *bcgh*, eighteen inches long and seven broad, is attached behind—sloping upward, so as to raise and pulverise the soil, and thus mingle it with the upper staple. The other figure represents Cotgreave's plough, manufactured by Ransomes and Sims of Ipswich,

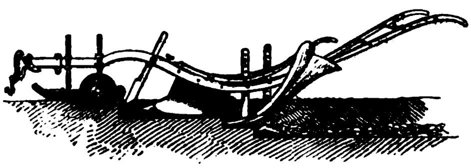


Fig. 27.

in which an ordinary plough is combined with a cutter and curved incline, which raise a portion of subsoil, and deposit it upon the top of the furrow-slice just turned over; while a coulter or cutter follows, at pleasure, to further break up the bottom. This implement promises to be invaluable in the work of heavy-land amelioration, or the intermingling of peat-soil with underlying clay—as practised in the fens—while other subsoiling ploughs, which simply break up without lifting, will be useful in destroying the hard pan under sandy soils, in disintegrating limestone rock, &c.

Mr Stephens's little book on the *Yester Deep Land-culture* contains a most admirable account of the improvements there effected on a large scale by draining and subsoil-trenching.

WOODS AND FORESTS.

Undoubtedly a very great extent of the royal forests and other wood-lands might be profitably grubbed up, and the land brought into cultivation. Wychwood, in Oxfordshire, about 4000 acres, has just been de-afforested, having previously produced for the country only £100 clear annual return; though the soil is well adapted for tillage.

Exclusive of Windsor, the fourteen royal forests lying in various counties from Hants to Durham, cover at least 48,000 acres, capable of yielding a princely revenue, if properly planted, thinned, and generally managed; but having really produced, until very lately, little or nothing.

The New Forest is a tract of 66,000 acres, of which little more than a quarter were wood-land in 1849. Half the land consists of most excellent soil, the remainder being poor, barren, and worthless. Until very late years, there has been an annual deficiency, though the property ought to return at least £60,000 a year. In Nottinghamshire, Mr Evelyn Denison has grubbed up some extensive oak-woods growing on a red-clay soil, at a total expense of £17 per acre, and has found that in every case the timber, &c., upon the ground defrayed the entire expense, and left a surplus of £5 to £12 per acre—the increased annual value being about £1, 4s. per acre. Many thousand acres of our national forest-land might be similarly treated with the same advantage.

But besides bringing woods and forests into cultivation, immense quantities of land may be added to our present arable and pasture, by the simple removal of useless fences, and curtailing the dimensions of those which are really requisite and necessary. Thus, around Exeter, the loss of land from the size and number of hedgerows amounts to no less than one acre out of ten; and in some districts of Norfolk, again, a like proportion of ground is thus wasted.

SPADE-HUSBANDRY.

Fig. 28.

The reclaiming and culture of small pieces of land by means of the spade and other instruments of manual labour, is usually spoken of under the name of spade-husbandry, but is also sometimes called cottage-farming or field-gardening—the operations of the culturist bearing an intimate resemblance to those applied in ordinary kinds of gardening.

It is very common for persons to argue against the practicability or advantage of settling the poor and hard-worked or out-of-work population on tracts of waste land—say in cottages with twenty acres, ten acres, or considerably less, to each family, assuming as the basis of their calculation that the cottager would make no more return from the same area of surface than the farmer who tries reclamation on a great scale. But innumerable facts contradict this assumption. Thus, the cultivation of the Bagshot sands has been attempted by many practical farmers, and afterwards abandoned; but it is a fact, that when the labourer puts his spade into this soil, he almost invariably succeeds in turning it into good potato-ground.

In his *Report on the Farming of Cornwall*, Mr Karkeek says: 'As a proof that a large part of the granite waste in the Land's End district would pay an almost immediate profit to the cultivator, I have only to state that a very considerable extent is now in progress of reclamation by cottagers, who obtain small plots of waste on leases of three lives, which they cultivate and build cottages on. When not very rocky or boggy, the land may be reclaimed at £5 to £6 per

acre—fencing not included, which varies according to circumstances. On taking ground of this description into cultivation for the first time, the cottager does not attempt to grow wheat, but potatoes and oats; in the course of five or six years he introduces barley; and in ten or twelve years, wheat. . . . . An immense breadth of waste on the slate-formation has also been reclaimed by cottagers, chiefly miners. The soil is exceedingly thin, resting on red or yellow gritty clay and coarse slates, abounding in quartz fragments, and traversed by mineral lodes and elvan rocks in every direction. The late Earl of Falmouth and Lord de Dunstanville gave a great impetus towards the reclaiming of this coarse kind of land, by granting pieces from three to five acres to cottagers on leases of three lives, at a small rent of from 2s. 6d. to 5s. per acre, on condition of their building cottages on the holding. The parish value of these lots now averages from 10s. to 20s. per acre. The Earl of Falmouth has nearly 2000 tenements of this description, which have increased in value, since 1815, from 20 to 25 per cent.' It is supposed that no less than 6000 working-miners are possessed of cottages on land which they have reclaimed.

In one district of Lincolnshire, called the Isle of Axholme, the occupations are remarkably small, a great number of farms being under ten acres in extent, while single acres, half-acres, and even roods are general over large tracts of open-field land. The soil is a very rich sand-loam, managed chiefly by the spade, hoe, and fork, and yields abundant crops to the constant and complete tillage and cleaning which it receives. Potatoes, onions, and other garden produce form a large proportion of the cropping. Many of these small cultivators may be poor, especially those who, having been too eager for a plot of land, have borrowed too large a proportion of the necessary capital, and so fallen into the clutches of mortgagees; but as a general rule they are well off, earning an independent though frugal livelihood. Perhaps one-fourth of them are owners; and there is a constant emulation among the remaining occupiers to become proprietors by a thrifty industry, great prices being consequently given for small plots of land. On the rich soils of the Isle, where toil is the principal requisite in cultivation, an industrious family succeeds well in spade-husbandry; though on light lands, needing the trampling of the flock and the expenditure of heavy sums in artificial manuring, the man whose chief capital is in his sinews would be at every disadvantage; though even there it is found that, by taking an acre or so of garden-ground, the labourer is amply benefited.

And if these examples are insufficient to shew the desirableness of extending cottage-farming and spade-husbandry, we have only to refer to the prosperous cultivators of Belgium and Flanders on this system—distinguishing between the industrious habits and skilful husbandry, both in tillage, rotation of crops, and manuring, found in those countries, and the absence of these essentials of success in so many parts of Ireland, where small-farming does not preclude poverty.

We will now consider the general management and practical details of cottage-farming. The homestead is to consist of a cottage with several apartments, which, with every convenience of copper, oven, well, outhouse, &c., can be erected for £70 or £80; a cow-house, pigsty, and barn. The size of the farm is supposed to vary from three to six, eight, or more acres, according to the capital and amount of labour which the occupier possesses, and to be laid out in a suitable number of field-plots by proper fences. If the land be in a waste condition, it must be cleared and drained. If moss, dig open drains round it to draw off the water; scarify the surface with the spade, and burn the heaps of turf; scatter the ashes over the land, with any sandy material or lime which can be procured, and then delve all from one end to the other. If the land be choked with stones or roots, all these must be removed to the depth to which the after-digging will have to go. In the case of strong or clay land, under-drainage will be necessary; and this is easily effected in small plots of land, when there exists an adequate outfall, by burying broken stones, thorn-fagots, &c., in drains three or four feet deep and moderately near together.

The tools required by the cottage-farmer are simple and inexpensive. They consist of two or three spades of different sizes; one or two of the light steel digging-forks now manufactured, which wonderfully reduce the labour of delving soil that has been stirred before; a pickaxe, hoes, rakes, scythe, reaping-hooks, hay-forks, flail, wheel-barrow, &c., according to means. A grinding-stone and a few carpenters' tools are also exceedingly useful. No horse or paid servant is kept, all the work being supposed to be done by the manual labour of the farmer and his family. The live-stock consists of a cow or cows, pigs, and poultry. To preserve manure without waste, a pit should be provided adjoining the cow-house, into which all the solid refuse and all that may be collected from the dwelling-house is to be removed. Liquid manure, and the drainings from the cow-house, &c., should be collected in a barrel sunk in the ground, and protected from the air. This is a most valuable liquid for throwing over the land to feed a young growing crop, especially for grass, &c., mown for the cow. A few shovelfuls of earth must be laid upon the solid manure whenever a layer of it is added to the quantity in the pit, so as to arrest the escape of any volatile and offensive gases during the process of partial fermentation. Rubbish of all kinds, withered leaves, stalks, clippings of branches, roots, &c., should be gathered into a heap, and occasionally moistened with urine from the cow-house, or mixed with a little lime, so as to rot down into valuable manure.

Whether it would be preferable to devote a cottage-farm to a mixture of green and grain crops, as in ordinary husbandry, or make it chiefly a dairy-farm, in which the raising of green crops for fodder is the main object, must depend on local circumstances. Generally speaking, it will be found advisable to make the maintenance of the cows the principal object, the crops consisting of rye, lucerne, clover, Italian rye-grass, cabbage, tares, mangel-wurzel, turnips, wheat, and oats; the cows being kept on straw and roots in winter, and upon green fodder mown for them during the summer. Of course, the animals must not be allowed to graze on any portion of the artificial grass crops; but being fed in a shed or lodge, may have a small open space in which to move about for their health. It is found that not only the cow gives a great deal more milk when kept warm in a house, but that the land yields a much larger proportion of food for her than when she is suffered to depasture and trample it. Indeed, three roods, or half an acre of artificial grasses, according to the application of liquid manure to the surface after each cutting, will suffice to keep one cow. There may be more than one crop in a year on part of the land: say that rye is the first thing cut green in spring, dig the land, manure, and sow mangel and turnips; the next cutting is of winter barley and tares, which are to be followed by late-sown turnips and planted cabbages; and the Italian rye-grass and clover yield several successive cuttings in the course of a summer, by plentiful waterings with liquid manure.

A portion of ground is to be set apart as a garden for potatoes, parsnips, carrots, onions, cabbage, and various table-vegetables; a few currant and gooseberry bushes, and an apple-tree or two, a few flowers near the house, and perhaps a hive of bees, not being forgotten.

From many reasons, the spade is found to be a far more efficient cultivator than the plough; the soil is not only deeply broken up, for the penetration of the roots of plants and for the admission of fertilising rain-water and atmospheric air from which the soil is

continually absorbing gaseous nutriment for crops, but it is more completely subdivided and pulverised; there is no glazed pan, as left by the sliding pressure of the plough, to oppose the descent of rootlets, of water and air; and by the more accurate inversion of the soil, the seeds of weeds and larvæ of insects which are about the surface are turned down and destroyed. The greatest advantage of spade-husbandry is in the trenching or very deep digging which can be practised. Instead of recruiting the productive power of the land by fallowing, as in ordinary farming, the cottage-husbandman brings up an under-stratum of soil to take the place of that which has been bearing a crop upon the surface. This layer, which we may call No. 2, lies, say from nine to eighteen inches below the surface, supposing a nine or ten inch spade to have been employed in the ordinary digging. After two or three years' cropping, a considerable portion of the manure delved in will have been washed down and imbibed by this lower stratum, and the upper layer will have been largely robbed of the mineral ingredients necessary for the sustenance of good crops. The art, then, consists of raising up this layer, No. 2, and turning down No. 1 in its stead. In some districts, the depth of available soil may not be so much as eighteen inches, the layer beneath being rock or chalk; in which case it will often be worth while to expend great labour in gradually breaking it up with the pick, and incorporating portions of it with the upper soil. Indeed, in no case is it advisable to bury the top staple at once, and attempt to grow a crop upon the raw, unmitigated, unameliorated subsoil brought up in its place; the principle is, to deepen gradually, bit by bit, and so, in effect, add to the extent of land cultivated without increasing the superficial area.

The Rev. Mr Smith, of Lois-Weedon, Northamptonshire, obtains immense crops by following this principle, together with that of having fallow-intervals between the rows of cropping. By deeply burying farm-yard manure, and well dressing with guano, superphosphate of lime, &c., beside, he produces thirty-eight bushels of winter beans and fourteen tons of carrots upon the same acre of land—the beans being in single rows, no less than five feet apart, and the carrots in rows between. This he finds very profitable; and besides interlining various other root or green crops with success, he grows wheat without a particle of manure year after year upon the same fields, with an average yield of thirty-four bushels per acre, and a profit of £5 per acre, with wheat at £2 per quarter. The wheat is in triple rows, one foot apart in the rows, with intervals of three feet. The intervals are dug two spits deep before winter, scarified in spring, and horse-hoed through the summer; this stirring being found to feed the corn-plants growing on each side, as well as prepare a fine and fertile seed-bed for the rows of wheat the following year. The wheat-rows and fallow-intervals succeed each other alternately, the same strip being thus bare-fallowed every other year; and it is found from a long course of years, both on clay and gravelly land, that the annual produce, reckoned for the whole field, equals that which other farmers obtain only once in two years. The cottage-farmer will do well to make himself acquainted with the particular directions laid down in Mr Smith's pamphlet, the *Word in Season*, and in his little book entitled *Lois-Weedon Husbandry*, as we believe tillage, such as that which a small occupier can accomplish with facility, has never before been brought to produce such remarkable returns, alike in produce and in a cleanly condition of the land.

In working a cottage-farm, unremitting industry is required; and it should be an object to make the very most of every day out of doors when the season and weather permit, and to occupy the dead of winter and days of bad weather at work in the barn or house. Trenching an acre two spits deep will take from thirty to thirty-five days; and one-spit digging ten inches deep, from twenty to twenty-five days, according to the nature of the soil. To make ridges for potatoes, plant the sets, mould them up with the hoe, and finally take them up, will take about twenty-four days for one acre. In digging, it should be borne in mind that a man can effect about one-sixth more work with a proper steel fork than he can with an ordinary spade.

In a report of the Emigration Committee, published some years ago by the House of Commons, is the following estimate of the expense attendant upon the location of a family, consisting of a man, his wife, and three children, upon four acres of waste land fit for cultivation, in any part of the United Kingdom:

	£	s.	d.
Transport of the Family—say, on an average, 50 miles—to their location,	3	0	0
Implements,	2	10	0
Household Furniture,	5	0	0
Cottage, Cow-shed, and Pigsty,	26	0	0
Potatoes and Seed,	4	0	0
Provisions for one year,	25	0	0
Cow, Pig, and Poultry,	9	0	0
Proportion of the Cost of Superintendence,	0	10	0
	£75	0	0

The items for the buildings and the live-stock are much too low for the present day, so that £100 will be nearer the sum required. It was considered that by the produce of the four acres cultivated by the spade, the family could maintain themselves, and, after a lapse of five to seven years, dispose of produce to the value of £22 per annum, after paying £8 yearly rent.

A cottager is described, in the *Cottage Farmer's Assistant*, as keeping two cows upon three acres of light land in Sussex, with the following results:

					£	s.	d.
278 pounds of butter, in 6½ months, sold at 1s. per pound,					13	18	0
Skim-milk, sold for 3 pints 1d., or given to the pigs, estimated for the year at					10	0	0
Two Calves, sold for					5	18	0
Half an acre and 8 rods of land, yielding 19 bushels of wheat, at 8s.,					7	12	0
A quarter of an acre, producing 14 bushels of oats, at 4s.,					2	16	0
Making a gross produce off half an acre of pasture, and 2½ acres of arable, of					40	4	0
Rent, Taxes, and Tithes,	£12	12	6				
Seed,	2	0	0		16	12	6
Hired Labour,	2	0	0				
Making a clear profit of					£23	11	6

And the butter looked for in the remaining five-and-a-half months was expected to make a total gain, from the labour of the cottager and his wife, of £30.

We have not space to enter upon the subject of the use of the spade in conjunction with the plough on farms large enough to support a team of horses; but it is placed beyond a doubt, that more produce is raised for human subsistence—space, soil, and climate being equal—by small farmers using only manual labour, than by large farmers with horses and ploughs.

In these days of farming-capitalists, and the appliance of steam-power, not only to mill-work, but the tillage of estates, the claims of the poor to a share of land, and to independence, as a prospective reward for their industry, are not very likely to be remembered; but if it be true that the system of large tenancies, and still more of monopolised proprietorship, has not been able to prevent a decrease of our rural population, and an immense amount of pauperism, it becomes high time for the community to demand that the waste grounds be utilised, and the people provided with the means of earning an honourable livelihood in that healthy and ever-coveted employment—the culture of the soil.

THE KITCHEN-GARDEN.

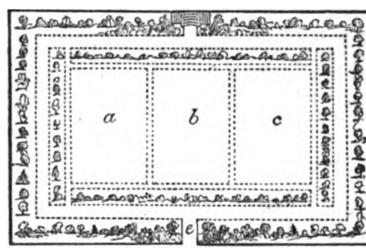
GARDENING, whether regarded as an ornamental art, or as a branch of industry, has long been cultivated with success in the British Islands, and has, in fact, become more intimately identified with the English people than with any other nation. Happily, many advantages of a public kind are now afforded for the gratification of our love of gardening. The Royal Garden of Kew, the model-garden of the world, is now the everyday resort of pleasuring parties of all ranks of society—from the humble artisan, whose holiday comes once a year, to the rich noble, whose life is one long holiday. The Crystal Palace at Sydenham, the Regent's Park Botanic Garden, and the 'marine gardens' (vivaria) of the Zoological Society, are additional sources of delight to all lovers of gardening in London; while the inhabitants of Scotland have the Royal Botanic Garden at Edinburgh, with its new palm-house and noble heaths and ferns, the Experimental Garden of the Caledonian Horticultural Society, and the Botanic Garden at Glasgow. Ireland is fortunate in its Botanic Gardens at Dublin, Belfast, and Galway. The provincial public institutions of this kind in England are numerous—as those at Cambridge, Oxford, Sheffield, Manchester, &c. But the possession of such public gardens does not satisfy the people; for gardens are like libraries—the enjoyment of a public one leads every man to wish for a little paradise of his own.

There are various kinds of gardens—the Italian gardens, with their splendid terraces, vases, and statues; the old French gardens of Le Notre, of which we have a specimen at Versailles, with their long straight walks, clipped hedges, formal parterres, and fountains; English gardens, with their elegant blending of natural with artificial beauty; and so on. But it is to none of these princely kinds of gardens that we intend, in the present series, to direct attention. We propose to treat of the three departments which belong to the greater number of gardens of the middle and humbler classes; those, in short, which, designed on a moderate scale, are intended to afford the three staples of garden culture—*vegetables* for the kitchen, *flowers* to charm the eye, and the more easily attainable kinds of *fruit*. These various articles are for the greater part the production of one garden, a section or scattered part being set aside for each; but for the sake of clearness, we shall confine ourselves in the present sheet chiefly to the economy and products of the kitchen-garden.

CHOICE OF SITUATION AND LAYING OUT OF GARDENS.

A garden of the ordinary mixed description varies from the eighth of an acre to a whole acre; but the most common size in country places is about half an acre. Whatever be the dimensions, the garden ought to be enclosed with a wall from ten to twelve feet high, and the ground thoroughly drained. Besides a wicket or small door for ordinary entrance and exit, there should be a gate that will admit a cart, to take away produce or bring in manure. A much more important circumstance than size or external appearance, is exposure. In a flat country, the garden must of course be level; but if there be a choice as to situation, select by all means a spot which lies with an easy slope—an angle, for instance, of fifteen degrees—towards the sun at his meridian. In the British Islands this will be facing the south. The next best exposure is towards the south-west, and after that the west. Avoid a northern or eastern exposure. An exposure towards the morning and mid-day sun, even though at a very small inclination, is as good as being many degrees further south; hoar-frost on the grass and plants will be melted within an hour after sunrise; whereas if the garden lie in the smallest degree away from the sun, the hoar-frost will remain unchanged perhaps the whole day. Allow no house, wall, or trees, to interrupt the fair action of the morning sun on your garden; for the sun is the main agent in bringing vegetation to perfection, and if you be deprived of it, your operations will be blighted and retarded in every possible way. So important are the sun's rays, that if your garden be small, rather have no wall on the south and west sides, but only a low fence, than submit to their exclusion. Some gardens are so disposed that they receive the sun in abundance in summer, but only partially the rest of the year. These gardens are imperfect. The garden should be visited all over by the sun daily, except perhaps in the heart of winter, when his rays have comparatively little effect. The exposure should also allow a free admission and currency of air; for this reason, a garden is best away from dense old woods, and is most advantageously placed in an open sloping lawn, overlooked by, or near the house of the proprietor. There should be an abundant supply of water readily at hand, for 'water is the life and soul of a garden.'

The shape of a garden is of little consequence. It may be square, oblong, semicircular, or irregular, according to taste or local circumstances. In the greater number of instances, an oblong, as represented in the following plan, will be found most convenient. It is surrounded



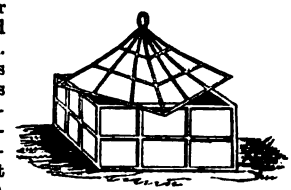
by a wall, in which is an entrance marked *e*. Within the wall is a border of several feet wide, and dotted round with flowers or flowering shrubs. Next is a gravel walk; and within is another border containing fruit-bushes, or perhaps fruit-trees on espaliers, and in the centre is the body of the garden laid out in three plots, marked *a*, *b*, and *c*. Between these plots and around them are paths (represented by dotted lines) of twelve or fourteen inches in width, not for ordinary walking, but for admission to the various plots or sections into which the ground may be divided. These paths are only flattened by the foot or by the spade, and are to be delved up annually in the course of digging. At the opposite side of the garden from the door there may be an arbour or summer-house fitted up according to taste, and overhung with honeysuckle, jasmine, or other climbers.

The regular walks in all moderately sized gardens should not be wider than three feet, at least where land is of value. Much care is required to keep walks in order, for they are very liable to shew crops of weeds and grass. To prevent this, as well as to guard against worms, which are very apt to disfigure the walks by throwing up casts, it is a good plan to bottom the walks well with broken cinders or slag from furnaces. Over a

smooth bed of this kind put a layer of small gravel that will bind, or, failing this, a layer of brayed yellow ashes from a furnace, if they can be procured. Smooth all with the rake, and flatten with a roller. Such walks should be scuffled with the Dutch hoe, raked, and rolled down several times during the season, otherwise the growth of weeds and moss will render them untidy. On no account should such operations be neglected until *Poa annua* and other grasses have shed their seeds, otherwise it will be impossible to get the walks thoroughly cleaned. Many small flowering plants—such as daisies, Virginian stock, thrift, and the spring potentilla—are used for edgings to walks; but if not constantly attended to, they straggle over the borders. The most effectual, and also the prettiest edging, is dwarf-box. It is easily planted in an even row, grows readily and regularly even under the shade of trees and amidst the smoke of a city, requires little trouble in trimming, and throughout summer and winter is ever fresh and green.

The above remarks will suffice to indicate the mode of forming walks in a common kitchen-garden of ordinary dimensions. Where the garden is more extensive, and is intended as much for ornament as utility, more care will be required, for nothing conduces so much to the tidy appearance and comfort of a garden as the neatness of its walks, especially in wet weather. Mr Glendinning has recently submitted some valuable suggestions on this subject to the Horticultural Society of London, to a few of which, notice may be called. In the first place, both verges or edgings of a walk should be of the same level, whether it be formed on level, ascending, descending, or unequal surface; by this arrangement, both sides will be equally affected by the rain, which so frequently disturbs the surface; and such walks are more agreeable than those having an inclination from one verge to another, and are more in keeping with the rules of good taste. To a refined eye, a walk whose verges follow natural inequalities of surface, resembles a building standing at a right angle to the sloping bank on which it is erected—after the manner of the leaning towers of Bologna. Good provision should be made for carrying off the rain, for which purpose, earthenware tubing is employed, of a diameter proportionate to the extent of walk to be drained. This is laid in the centre with communicating tubes to the sides, where square cess-pools, about 9 inches square and 18 inches deep, built in brickwork, should be formed to receive the water and sand, &c., a grating being placed over each cess-pool. Where the walk takes a precipitate fall, it will be necessary to have surface tile-gutters along both sides, or sea-pebbles may be used with good effect. The geological formation of the neighbourhood must be the guide as to the material to be employed in forming the walks. Broken stones, rubble, or clinkers, constitute a good foundation; a foundation of nine inches is sufficient. Concrete or asphalt is sometimes used for the surface; but good gravel, where obtainable, is to be preferred. 'It is more congenial to our feelings, and harmonises better with the surrounding scenery of the garden.' The surface of a walk should be nearly level, with only so much convexity as to readily throw off the surface-water.

No precise directions can be given respecting garden tools and apparatus; the following are the articles required in moderately sized gardens of a mixed kind: Spades, a trowel for lifting flowers, Dutch and common hoes, iron rakes, a strong clasp-knife for pruning, pruning-gloves, a pair of strong pruning-shears, an axe, a hand-saw, a hammer and cast-iron nails, a wheelbarrow, a roller, a dibble and line, a watering-pan, a ladder, flower-pots of different sizes, conical earthenware blanching-pots, bell-glasses, and glazed frames of different sizes. These frames may be had either in one piece or with a movable top, as in the following figure. A neat small kind, framed in zinc, useful for protecting early seedlings or flowers, may be had in London for 1s. 6d. each. Other utensils employed by gardeners—such as forcing-pumps to wash wall-trees, fumigating bellows, &c.—need not be particularised. A person possessing only a small garden will shortly discover by experience what are the articles required in his operations. The articles constantly in use are the spade and rake; with these alone many a small garden is successfully cultivated, and the amateur with whom economy is an object, will do well in entering for the first time upon a little garden of his own, to begin with the spade and rake, and allow experience to suggest further wants in the tool department. For gardens in which cucumbers and melons are to be grown, glazed frames and brick-built pits will be necessary. As already indicated, it is a great advantage for a garden to have a command of good fresh water for the purpose of irrigation, and also a small pond in which aquatic plants can be grown. If water is procured from a pump-well, it should be allowed to stand in the open air in a trough for at least a day before being poured on the plants. By this means it gradually acquires the temperature of the atmosphere.



A garden is in all cases laid out according to the taste or fancy of the proprietor; but there are certain general rules which all follow. The wall is reserved for fruit-trees. As fruit-trees require much air and sun, the borders must not be clogged up with bushes, peas, or any other tall vegetables. The borders should either be reserved entirely for the roots of the wall-trees, or contain only small articles which are delved up yearly, because the soil at the roots of the trees requires occasional renewal and loosening, and these operations cannot be done if the ground is encumbered with permanent plants. If a row of gooseberry or other small fruit-bushes be placed on the borders, they should be near the outside, and not less than ten feet apart. Let it be observed also, that flowering-plants should occupy the border most exposed to the sun; while horse-radish, and others naturally loving the shade, should be placed on the south and west borders, from which the sun's rays are generally less or more excluded.

The body of the garden within the walks is laid out in larger or smaller plots, according to taste. These plots are generally oblong, and are subdivided into sections, rows, or beds, for the different kinds of kitchen vegetables. In the corner of one plot are the cucumber and melon pits, partially secluded, but not shaded by hedges or bushes. In different corners are plots, and round the edgings are the flower-parterres, disposed to meet the eye, and to be easily accessible from the walks. In some gardens, much of the ground is overshadowed by fruit-trees. This is seriously detrimental to the growth of the plants beneath, exhausts the soil, and prevents the proper flowering and fructification of every vegetable within reach. Permit no tree to overshadow your ground; the only allowable places for trees are the walls and narrow espaliers running up one side of the central plots. When a garden possesses the addition of an outside strip, enclosed by a hedge, the exterior sides of the walls may be lined with fruit-trees, and the ground laid out for potatoes and other common vegetables; it will also afford the most proper site for compost dung-heaps, forcing-pits, and the like.

PREPARATION OF THE SOIL—COMPOSTS—TRENCHING.

The soil of a garden should be deep, rich, and easily penetrable. Whatever it may have been originally, the soil admits of vast improvement, and no trouble can be

considered too great to bring it into a good condition. If shallow, trench it so as to loosen the subsoil and gradually bring it into operation above. In many instances the soil is too stiff or clayey. Such a soil may not be unfit for plough husbandry, but it is out of place in a garden. The method of loosening and meliorating a clayey soil, is to give it a large volume of sand and vegetable manure, which may be delved in at the winter digging, and at the spring digging, the new and old materials will be well mixed. In general, too little attention is paid to adding sand as a restorative; such is absolutely necessary in all soils except those of a very sandy nature, because every crop actually carries away a certain proportion of the silica lodged in the soil. If the soil be already too sandy, it may be assisted by clay, silt from ditches, &c. Whatever be the nature of the soil, it should be thoroughly pulverised. Lumps thrown up by digging at the commencement of winter are pulverised by the frost, and imbibe nutritious gases from the atmosphere. In spring, all should be well delved, every spadeful being cut and broken as it is turned down, and no hard part left impervious to the tender roots of the vegetables. Every particle of soil should be capable of doing duty in feeding the plants.

No garden can be conducted with the least advantage without giving it regular manuring. If you hunger a garden, it will hunger you in return. In connection with every rightly managed garden, there must either be a compost heap, in which dung is preparing for use, or there must be some means of readily purchasing old manure when it is required. The manures employed are the same as in Agriculture; but being required for a more delicate purpose, they must in general be well rotted, and ready to unite with the soil. A compost dung-heap is prepared by putting alternate layers of stable-dung, or night-soil, &c., with earth, peat-moss, decayed leaves, and general refuse of vegetation, turning the whole occasionally till the mass appears to be sufficiently decomposed for use. A small quantity of this stuff will often be required to place at the roots of plants.

Near large towns, where there is a constant demand for kitchen vegetables, market-gardens are established for producing the required articles in variety and abundance. The finest market-gardens in the world are near London, where the soil is deep, and any quantity of manure, in the form of night-soil, from the metropolis, is easily obtainable. The plan on which these gardens are conducted might serve as a model for all kitchen-gardeners in this country. It is thus briefly described in the article Gardening in the *Penny Cyclopædia:* 'The gardeners' year properly begins in autumn, when the land is dug, or rather trenched, and well manured. Various vegetables, which will be required in winter, are now sown, and especially those which are to produce plants to be set out in spring: spinach, onions, radishes, and winter salads are sown, and when the weather is severe, are protected by a slight covering of straw or mats. In February, the cauliflowers, which have been raised in frames or under hand-glasses, are planted out. The cabbage-plants are pricked out. The radishes, onions, and salads go to market as soon as they are of sufficient size, and sugar-loaf cabbages succeed them. As the cauliflowers are taken off, they are succeeded by endive and celery, and the same is the case with the cabbages. Thus there is a constant succession of vegetables, without one moment's respite to the ground, which, in consequence of continual stirring and manuring, maintains its productive power. Deep trenching in some degree prevents that peculiar deterioration of the soil which would be the consequence of the frequent repetition of similar plants. This effect is most perceptible when the plants perfect their seed, which is seldom or never allowed to take place in market-gardens; but great attention is paid to the species of plants which succeed each other on the same spot. The principle which experience and theory unite in establishing, is that of avoiding the too frequent recurrence of plants which belong to the same natural families. The greater variety cultivated in gardens, in comparison with the common produce on a farm, enables this principle to be fully acted upon. Those gardeners who overlook this, and repeatedly sow or plant the same kind of vegetables in the same spots, are soon aware of their error by the diminution of the produce, both in quantity and quality, and by various diseases which attack the plants, however abundant may be the food supplied to them, or however careful the tillage.

'The principle on which the gardens are cultivated, is that of forcing vegetation by means of an abundant supply of dung, constant tillage, and occasional watering. . . . . Those vegetables which arrive at a marketable state in the least time are always the most profitable, and those also for which there is a constant demand at all times of the year. . . . .

'The value of the produce in one year from an acre of garden-ground in the most favourable situation, as stated by Mr Middleton, from the account which he received from a market-gardener, is almost incredible. It is as follows:—Radishes, £10; cauliflower, £60; cabbages, £30; celery (first crop), £50; (second crop), £40; endive, £30: making a total of £220 for the gross produce of an acre in twelve months. The expenses of cultivation are no doubt great. In inferior situations, the produce is much less, but the expenses are also somewhat less. When it is considered that there are nearly 2000 acres thus cultivated, the gross amount of produce must be very great.'

GENERAL OPERATIONS.

Digging or *delving* with the spade is the principal means of garden culture. The spade usually employed is ten inches deep in the blade or spit; but as delving is not direct downwards, but sloped, the depth to which the spade goes in digging is seldom more than nine, and often not more than eight inches. In commencing to dig a piece of ground, take out a spadeful all along one side, and carry it to the opposite side where you are to leave off. Now begin at one end of the trench just opened; thrust the spade with the foot into the ground, taking about five inches in breadth, lift it up, and turn it over into the open trench, the top undermost, and the fresh earth above. Do the same with the second spadeful; and so on with all the others to the end of the line. Take care to dig always a uniform depth and breadth, so as to keep the line even, and the trench or open furrow of one width. If there be any weeds or loose refuse on the surface, put them in the trench, and cover them in; where the ground is dirty, all such refuse ought to be well rotted in the dung-pit, or, what is better, reduced to ashes, and then spread over the soil. Break or pulverise the mould as you proceed, and keep the fresh surface level. When you have delved row after row to the last, the earth laid aside will fill up the concluding trench. Ordinary digging is performed best in dry weather; but digging to throw up lumps for winter melioration should, if possible, be performed when the soil is somewhat moist. In this kind of digging, do not touch the lumps with the spade after throwing them up; for the more rugged and uneven the surface, the more thorough is the exposure to the influence of the frost.

Raking.—Hold the handle of the rake at an angle of forty-five degrees, and draw it lightly over the surface of the newly dug ground. The object is not to draw earth along, but to smooth or comb down the irregular surface, and to bring away any loose refuse or stones. Like digging, it should be performed in dry weather.

Marking with the Line.—The gardener measures and marks off all his figures in the ground with his line and spade. With the line he can draw a circle round a

central pin, or make an oval from a union of two circles, or form semicircles, spirals, triangular spaces, or polygons. When he wishes to make a small path between rectangular plots, he sets his line accordingly, and walking along it, with a foot on each side, he tramples down the earth from one end to the other, and then he can smooth it and beat it down with his spade.

Hoeing.—With a common hoe, the earth is cut and drawn towards the operator. The object of hoeing is to draw up the earth so as to cover the lower parts of the stems of plants growing in a row. In hoeing weeds, which is done by a different implement, the Dutch hoe, cut off the weed beneath the surface, and do not cover the stalks, which are to be raked away, and placed on the dung-heap. Weeds, especially such as dandelion and groundsel, whose seeds become winged when ripe, should be hoed and removed before seeding. As many such weeds which infest gardens are blown into them from adjacent roadsides, it would not be misspent time to clear the neighbourhood periodically.

Animal Annoyances.—All gardens are more or less exposed to the destructive inroads of wild animals. Hares and rabbits not only gnaw the bark off the stems or lower branches of trees, and also the buds in season, but are also very destructive to vegetables and flowers. To prevent the encroachments of these quadrupeds, the garden ought to be properly fenced; but if they get in notwithstanding, the trees may be saved by smearing the lower parts with a mixture of cow-dung, soot, and water, reduced to the consistency of thin paint; a smearing of tar will also answer the purpose. Moles, rats, and mice may be caught by trapping; moles also are said to be got rid of by placing slices of garlic, or onion, in a green state, within their holes, as they have a great antipathy to the odour of these vegetables.

Birds are sometimes an annoyance, particularly when new-sown peas or seeds may be easily scratched up. But, though in some instances injurious, it is believed that on the whole their visits are beneficial; for they pick up large quantities of slugs, insects, larvæ, or caterpillars of different kinds. Wall-fruit may be preserved by nets, or by the more simple method of fixing horizontal lines of black worsted in front of the trees; the repeated ineffectual attempts to alight on these lines are said to scare the animals, and cause them to desist. Lines of threads, along which feathers are fastened, are employed in many cases to protect beds of seeds from birds, but are only partially successful.

Insects are the grand pest of gardeners; their appearance is so mysterious, and their devastations so varied, that all schemes to extirpate them are often ineffectual. They are most destructive in their first condition of larvæ or caterpillars. In this state they should be removed by the hand from kitchen vegetables. To destroy the smaller kinds of larvæ, fumigation of tobacco-smoke, by means of a fumigating bellows, may be employed with advantage; and the plants may be cleansed with a syringe and water. For the cleansing of fruit-trees from insects, we refer to our article on FRUIT-GARDENING.

Slugs are another chief annoyance, especially in low-lying shaded situations. A little salt destroys them; but, as in the case of caterpillars, the best plan is to clear them out on their first appearance, by the hand. Worms in the ground are not considered injurious. Salt kills them.

Sowing.—The greater number of garden vegetables are reared from seeds, which are sown at certain seasons in the ground. Some seeds, such as peas, are sown in drills, the hand deliberately dropping them in a straight shallow trench. Other seeds, such as those of onions, leeks, cress, &c., are sown broadcast, which is a thin and equable scattering over a bed prepared for the purpose. There is no necessity for any species of sowing-machine in a common kitchen-garden. Most seeds, peas included, require to be pressed down by treading or gentle rolling, and then covered up by the hoe or rake. All seeds should, if possible, be sown and covered up in dry weather.

Planting.—Many vegetables require to be removed while young from the bed in which they were grown from seeds, and planted out in rows. Having adjusted the line, commence at one end of it; pierce the earth with the dibble, and into the hole so made, insert the root of the plant, and pierce the earth at its side, so as to press the mould round the root, leaving no vacant space below. The common error in planting is injuring the tap-root and rootlets by careless pulling of the young plant from the nursery, by rudely using the dibble, or by pressing the earth too firmly round the collar, and neglecting to do so with the roots. If a plant is carefully transplanted in damp weather, it should never shew any symptoms of the change.

Watering.—In dry seasons, artificial irrigation is of great use for giving due liquid aliment to plants, and is indispensable to those newly transplanted as above, in order to consolidate the roots. Watering, for whatever purpose, is most advantageously performed in the morning or evening. If done during the time the sun is shining, take care not to water the leaves of any plant. If the day be cloudy and cool, watering the tops of plants can do no harm. The watering, in any case, should resemble as nearly as possible a soft shower, and be performed with a rose watering-pot. The greater number of flowers are injured by watering, if the water touches their petals.

KITCHEN VEGETABLES.

The vegetables usually grown in kitchen-gardens belong to various natural orders, which, for convenience, we shall arrange in the following groups:—1. The cabbage tribe of vegetables; 2. The pea and bean kind; 3. Those grown for the sake of their roots and tubers; 4. The onion and leek kinds; 5. Salads; 6. Sweet herbs; and 7. Miscellaneous kinds. This grouping, it will be understood, has only a partial reference to botanical arrangement, and has been adopted in preference to the confusion of common alphabetic lists. For the technical classification of the plants here treated, the reader is referred to the sheets on SYSTEMATIC BOTANY.

The Cabbage Tribe.

The vegetables of this group belong to the order Cruciferæ, having cross-shaped flowers, and have, in fact, been all derived from the one plant, *Brassica oleracea*, which grows on the shores of the south of England. The garden varieties of this plant—cabbage, savoy, Brussels sprouts, cauliflower, and Scotch kale—all so unlike each other, and so unlike their indigenous prototype, present a series of the most remarkable instances known of the power of man to induce modifications in the size, form, and structure of an organic being, and to sustain permanently the races thus obtained.

Cabbage (*White*).—The cultivated varieties of the common or white-hearting cabbage are very numerous. The best varieties in ordinary use are—1. Small and large York; 2. London Market; 3. Sugar-loaf; 4. Knight's Downton; 5. Battersea; 6. Vanack; 7. Drumhead; 8. Sutton's Imperial; 9. Atkin's Matchless; 10. M'Ewen's; 11. King of the Cabbages. The cabbage is a biennial plant; it runs a two years' course, bears seed, and dies. To obtain hearted cabbages throughout the year, two or three sowings must be made; one in the spring, another in summer, and, finally, one in autumn. Spring-sowing can be effected at once, or it may be divided into two or three operations; because, from the third week of March to the first week of May, the seed can be successfully sown for the supply of summer and winter. Yet by attentive management, one sowing may be made to produce all that a family can require: we restrict our directions to that simple operation.

Prepare a bed of good sound loam in an open exposure, and let it be slightly manured. Dig the ground for four rows, nine inches asunder, and from fifteen to twenty feet long. Break the earth finely, and leave it to settle for three or four days; then place boards to tread on, while a first drill, one inch deep, is struck by the line; make the bottom of this and every other drill even, and a little solid, by patting it with the back of the rake. Sow the seeds rather thickly, because it is better to thin out an abundance of plants than to lose the greater part of a thin crop by insects. When sown, cover the drill with fine earth, proceed to make and sow other drills, till the bed be finished, and then either tread the surface over with the feet placed nearly close together, or pat the surface with the spade, and then finish it off smooth with the back of a rake. Always avoid to tread ground into holes, and therefore recede from the work backward; prefer to use the feet in light sandy soil, but rarely with stiff and binding ground. In a very dry season, seeds will not easily vegetate; therefore in such cases strike the drills, and water effectually along them for three successive evenings, covering the plot with mats throughout the day. In the third evening, make the drills even, sow, cover with earth, sprinkle again, and lay on the mats by day, till the plants be visible, then dust them once with the finest road-sand while the dew is on, and in the evening with air-slacked lime. These precautions need not be repeated. We never saw a set of cabbage, turnip, or celery plants so dusted with road-sand that was much infested with the turnip-beetle; and as to slugs, lime, or lime with coal-soot, will effectually prevent their ravages, or destroy the vermin.

When the plants begin to produce their true leaves, thin them out, first to an inch asunder, and again to two inches; they will thus gain strength rapidly; and when they have three or four good leaves four inches long, they will be fit to go out, some into nursery-beds, and others to the plots where they are to remain. Those set in the former, six inches asunder, will acquire stocky roots, and be prepared for successional beds. The size of the plants will indicate the season during any of the summer months. Those planted permanently will require the ground to be made rich with manure, and the transition from poor to rich earth will make them grow rapidly. The smaller Yorks, &c., should stand twelve or fifteen inches apart, the large varieties, twenty to thirty inches. Set each plant as deep as the base of the lower leaves, and observe the directions given for the treatment of broccoli. These seed and nursery beds will supply the table from May to November, and in fine seasons, even later.

Red Cabbage is only used for pickling; it is raised by a two years' course—that is, by sowing in August, and transplanting, as directed above. The heads form in the ensuing summer, and are in fine condition in October. If sown in spring, little-hearted cabbages can be obtained, which may supply a loss, or serve as a substitute for the others. The large or Dutch red is the best.

The Savoy is very hardy, and, like the cabbage, forms a close round head, but the wrinkling of the leaves serves to distinguish it. Its culture is very easy. Begin to sow in February; sow a second time in March; a third—and this is for the main crop—in April, about the middle of each month. Let the situation be open, the soil a good natural loam, if possible, and laid out in a bed three or four feet wide, digged, and made fine. Scatter the seeds evenly, and rake them. Repeat, for the fourth time, in August. The plants of this last sowing will attain a large size by the following August and September, if planted out in April. Moist weather should be chosen for planting, and the savoys should stand two feet apart. Keep the ground clean, stir it occasionally, and draw the earth towards the stems on each side, always, however, leaving a sort of furrow three or four inches wide, to receive the rain, and convey it to the roots.

Brussels sprouts produce tall stems, three or four feet high, which support a head somewhat resembling an open savoy, of little value. The lateral buds down the stem protrude a succession of little green heads, like small savoys, of delicate flavour. The following is transcribed from the *Domestic Gardener's Manual*, wherein the Brussels practice is noticed, and a few experimental remarks appended:—'The plants are raised from seed sown in March or April, of which an ounce may be requisite for a seed-bed of four feet by ten. Van Mons says: "The seed is sown in spring under a frame, to bring the plants forward; they are then transplanted into an open border with a good aspect. By thus beginning early, and sowing successively till late in the season, we contrive to supply ourselves in Belgium with this delicious vegetable fully ten months in the year; that is, from the end of July to the end of May. The plants need not be placed at more than eighteen inches each way, as the head does not spread wide, and the side-leaves drop off." In England, the Brussels sprout is so hardy, that it will stand twenty degrees of frost; and its head about Christmas is a tender and delicate kind of greens. Being then cut, the plant will remain nearly torpid till the advancing sun causes it to start into new vegetation; then the spaces between the rows should have a little leaf-soil or good manure, lightly forked in; and the young heads, all of which were quiescent, but visible in the winter, will speedily advance from the axils of the leaves, and yield a supply for many weeks, if they be properly pulled or cut off in succession.'

Scotch Kale and German Greens.—These are raised by sowing the seeds either in beds or single drills late in February, or early in March; to be first thinned out to three inches apart, and finally transplanted to beds or rows, wherein the plants are to stand thirty inches asunder. The plants may go out in succession from June to the middle of July. The heads are cut first, and subsequently side-shoots arise, which produce excellent winter greens till early cabbages come in. The plant runs to flower and seed during the succeeding summer.

Cauliflower, which is grown only for its rich white heads of metamorphosed flower-buds, which form one of the most delicate and highly appreciated products of the *culinarium*, requires a warm and moist climate. In Holland, it grows to great perfection.

Spring sowing, for a first crop, may be made in March, over a temperate hotbed. The seedlings are to be pricked out when the leaves are an inch broad; and from this nursery-bed they are moved to the garden-bed in May, to stand more than two feet asunder, the ground being made extremely rich. The plants, after they begin to grow, are occasionally watered with the liquid manure collected from the drainage of dunghills. A second spring-sowing is made in the open border in May, to obtain plants from September to November, by a similar mode of treatment. The last sowing occurs in the middle of August. The plants, when about four or five weeks old, are to be thinned out to two or three inches apart, the best to go into nursery-beds of rich earth, three or four inches asunder. Here they must grow till November, when the strongest are to be set out in rows, to be preserved under bell or hand glasses. Dig a bed of rich ground in an open situation, and make it still richer with manure; set three or four plants together, five inches apart, in patches, each patch a yard asunder; give water, and cover close with a handglass till the plants begin to grow. When fairly taken with the soil, tilt the glasses on the sunny side with a brick, and thus continue to give air on mild days during the winter, and on some occasions take the glasses quite off, but replace them, and cover close every night. In the spring, thin the plants to two under each glass, making good any deficiencies with some of the best

plants thus taken up, and plant the surplus in a warm spot of ground two feet apart. Keep the glasses on the other plants, raising them more and more, occasionally exposing them to mild rains till about the beginning of May—unless in the event of intense frost, such as we have experienced within a few years—when the glasses may be finally removed. Cauliflowers will thus be produced in succession throughout the summer.

Other plants should, in November, be placed in frames four inches apart, in a bed of rich dry loam, over a very slight hotbed: give water, close the lights, and be guided as respects the admission of air by the directions for the hand-glass division. The lights should be covered with mats and boards during severe frosty nights. In February, March, and April, the plants are removed in succession to beds richly prepared; and the cauliflowers will come into perfection during July and August. It is customary to form the earth immediately around the stems into the shape of basins, to contain water or the liquid manure: it is a useful practice, and this, with hoeings between the rows, will comprise the general treatment.

Cauliflower requires a very rich soil, and a warm situation. In many localities, especially in Scotland, it will be found impracticable to plant out in autumn; the plants must therefore be protected in frames until the spring.

Broccoli is one of the best vegetables of the cabbage kind, and is valuable for coming at a season when not liable to be affected by caterpillars. There are various kinds of broccoli, but all may be arranged under two heads—those for spring use, and those for use from September to Christmas; the latter are termed 'Cape' or autumn broccolies. The most approved varieties for spring use are Bowles's new sulphur, Moody's dwarf, Grange's cauliflower, and Portsmouth cream or buff coloured.

One ounce of seed of broccoli is calculated to sow a bed four feet wide by ten long, broadcast, on a prepared bed; but if sown in drills, rather less seed will be sufficient. Each kind should have a place allotted to itself. The soil should be a fresh and rich sandy loam, and the season for sowing will be comprised between April and July. The plants of the Cape kind are finally set out in beds made rather rich with manure, at any time when they have leaves a few inches long; two feet distances, plant from plant, will be sufficient. Each plant is to be firmly secured in the soil. This species will come in season in August, and continue to produce a supply throughout the autumn; in mild seasons, some heads may be cut even so late as the turn of the year.

The spring hardy varieties are treated by most persons in the same way as the Cape—that is, the plants, when they are six or eight inches high, are transplanted as they become ready, between the first week of July and that of September, into beds of richly manured loam, and set two feet apart, the largest sorts, as the Portsmouth, at thirty inches, and they are kept perfectly free from weeds. If the seasons be favourable, a successional supply of broccoli is thus obtained from the first week of March to the end of May. It is also customary to lay down plants in September, with the heads turned from the sun, applying earth on the south side over the stems, to protect them from snow and frost. We prefer to plant in six-inch-deep trenches, properly manured, removing the plants to them when not less than a foot high, filling each hole with water, and repeating the watering for two or more successive evenings. This treatment, even in the driest seasons, will secure the plants; and as the winter approaches, by drawing the earth from the ridges on each side, and thus filling up the trenches, the stems will be protected, and the ground levelled and rendered light. We have practised this method during seven or eight winters, and have lost no opportunity to recommend it to others. Broccoli plants do better in trenches than any other members of the Cabbage family.

To save seed, it is only necessary to watch the progress of some very fine plants left late in the spring, to cut out all the weakly and crowding parts of the heads when expanded, and to secure the seed before it be quite ripe, or rather, before it is shed by the seed-vessels. But as all these plants pass, by crossing or hybridising, into other varieties, it is generally not desirable to attempt seed-growing.

Instead of growing kale, cabbage, cauliflower, or any other of these plants from seed, it will save much trouble to the cultivator of a small garden to purchase young plants by the hundred from a market-gardener.

The Leguminous or Pea and Bean Tribe.

Of the Pea there are various sorts, but it is only those of a fine kind which are cultivated in gardens, and called *garden-peas*, that we require to notice here. When fresh, they are a bright green, and when dry for seed, most are a buff yellow, others of a bluish-green hue. Peas are a summer delicacy, and the chief art is to produce them in the open air, by the middle of May, and to keep up a succession of crops till other vegetables supersede them. Skilful gardeners do not consider it a difficult process to effect an early crop, as the plant is very hardy, and sustains violent transitions without much danger. Peas, therefore, may be accelerated in frames and vineries during February, and being transplanted into rows fronting a south wall, will continue to advance progressively though the weather be cold. They can also be sown—provided there be no frost—in the open ground at any time. There are many varieties of this vegetable, but we shall notice only those that have proved themselves worthy of general culture. The Early Frame, Double Blossom, Prince Albert, Early Warwick, and Bishop's Dwarf, are adapted for very early crops, but their produce is somewhat less than some of the following later kinds, which ought to be chosen for a full crop: Prussian Blue, Imperial, Knight's Marrowfats, Scimitar-podded, Fairbeard's Surprise and Champion of England. In the two varieties of sugar-pea—the tall and dwarf—the pod is destitute of the cartilaginous transparent lining usually seen in the pods of peas; this enables the pods to be used in the same way as kidney-beans.

The soil in which this vegetable most luxuriates is a free, light, but rich loam, abounding with vegetable matter, but not manured with recent dung. The situation for crops from June to August should be exposed and open. Some obtain an excellent yield from seed sown early in November, in long drills, in a sheltered situation; and if the winter be open, success is nearly certain. At whatever season persons commence, a better general rule cannot be adopted than to sow for a successional crop as soon as the peas of the preceding sowing are fairly above the surface. The plants, when three inches high, should have earth drawn against their stems on both sides; after which, the soil may be superficially opened by passing the hoe lightly through it, and thin branchy sticks, of a height suitable to the habit of the variety, ought to be thrust into the ground, converging a little so as to meet at top, and interlace each other. Shallow soils over chalk are soon over-cropped by peas, and refuse to bring a healthy plant; and in all kinds of ground, the frequent repetition of pea-sowing is to be deprecated. The land must also be purified by a rotation of cabbage and potatoes.

In country gardens, the field-mouse is a great enemy to peas, and where these are sown in winter or early spring, when food is scarce, the seed is sure to become a sacrifice to its ravages. Many methods have been recommended to obviate this mischief; but the most effectual plan, according to our experience, is to make a pretty deep furrow, and after depositing the seed peas in it, to cover them with small bits of chopped furze, after which, the whole is covered in with earth in the usual

manner. The furze being prickly, annoys the mice in their attempts to scrape up the peas, and they soon desist.

Stakes for peas are indispensable in keeping them from trailing on the ground; and therefore every person who wishes to grow this vegetable in his garden, should take care to preserve the stakes from one season to another, as long as they are serviceable. Any kind of branchy twig, such as those of the beech and the larch, will answer the purpose; and the better if they are open and spreading: they must be stripped of their foliage. When all the pods are taken, remove the haulm or pea-stalks to the compost dung-heap.

Beans.—These are planted in rows, and the seeds are generally sown at different periods between the 1st of May and the middle of July. The situation should be open, not crowded by other vegetable crops, or under trees—the soil, a free working loam, moderately manured. The drills should not be nearer to each other than thirty inches, and not more than two inches deep. In these the beans are to be dropped at regular distances, not exceeding three or four inches. Make the ground firm at bottom, but let the covering earth be light, and only slightly raked, not trodden or made hard. The one leading principle of successful growth, is to bring the plants up as soon as possible, and this is effected by selecting warm weather and well-prepared open soil. A cold, wet, cloddy condition of the land causes decay.

The kidney-bean comprises two species of plants, which, though of one family, are of very different habits. Both, however, are natives of the East, and are very impatient of cold; hence the necessity of deferring the sowings till the weather be nearly settled in the spring, and the ground warmed to the depth of several inches. The two species are, first, the dwarf, with its numerous varieties, all bearing the title of *French beans*—being forms of the *Phaseolus vulgaris* of botanists—and, secondly, that commonly termed *scarlet runners*, from the scarlet colour of the flowers, although there are varieties with white and variegated blossoms: this is the *Phaseolus multiflorus* of botanists. There are few of the many varieties of the dwarf which can surpass the buff or dun-coloured bean—it is free of growth, and fertile, either when forced in pots, or planted in the open ground. The black speckled dwarf is also an excellent bearer; the white-seeded is the true *haricot* of the French.

Runners are planted with similar precautions, or if sown early in pots and boxes, will transplant very well. When the plants attain the height of three or four inches, they should have a little earth drawn about the stem, and be staked; that is, somewhat tall branchy sticks should be placed on each side, converging towards each other at the top: these props ought to be eight feet high; and when the plants reach their summits, they should be nipped off and kept stopped, to cause them to produce fruit-bearing laterals. 'Gather beans, and have beans;' that is, never leave any pods to ripen; if redundant, let them be given away, or go to the pigsty, for a maturing pod arrests the fertility of the plant by tasking all its powers. Keep the crop clean, and the surface of the ground rather open. The roots of the members belonging to this section are accounted narcotic and poisonous.

The garden-bean is known to every one. Though a native of Egypt, it is, in all its cultivated varieties, very hardy. These varieties are numerous: some of the more approved are—the early *mazagan* for the first crops, which may be sown from October to February; early *long-pod*, an excellent fertile bean for general use, not highly flavoured; *broad Windsor*, the best of all beans for flavour; and the *fan-bean*, which produces an abundant crop.

Beans prefer a sound and rather firm loam, retentive of moisture. They suffer much in a very dry season and soil, particularly if attacked by the black 'green-fly' (*Aphis Rumicis*). But the attacks of this insect are not so severely felt by the gardener as by the farmer, for its hordes soon overrun whole fields, preying upon the juices of the plants, and thus preventing the development of the grain. In the autumn, when these flies take wing, they form extensive clouds in the atmosphere, and collect in sheltered situations to such an extent as to spread terror among the inhabitants: this is, in fact, the so-called 'cholera-fly.' *Topping*, when the insects are first seen, appears to be the only remedy. The seeds should always be sown in rows. Beans transplant well, and therefore may be sown thickly in autumn, covering the plants with hoops and mats, or with a garden-frame and lights.

When the plants rise in the rows, or begin to grow after being transplanted, loosen the earth by pushing the Dutch hoe along the surface, and draw three inches of it to each side of the stems; or rather, shovel up two or three inches of the earth, and lay it flat a foot wide on each side of the row of beans, shelving rather towards the stems than from them, for then the rains would find their way directly to the roots. The seasons of sowing are autumn for the mazagan, January and February for long-pods, and from March to June for the Windsor. Sow succession crops one after the other, according to the demand, as soon as the plants of the preceding sowing shall be quite above ground.

As the beans ripen and turn black, draw them up, and place them to dry in an airy situation, guarding the pods from mice, which are rather partial to the bean.

Lentil.—Within the last year or two, this crop has attracted some attention: it must not be supposed, however, that it is now brought into cultivation for the first time, for it wears the crown of hoar antiquity, in common with wheat and barley, and other staple products that have in all ages formed the leading food-plants of man and beast; it is, indeed, the oldest leguminous plant of which we have any record, its nourishing qualities having been appreciated at a very early period. For bread and pottage of lentils, Esau sold his birthright, and the plant is still in common use in Eastern lands, being parched in frying-pans, and commonly sold in the shops in Egypt and Syria. The following varieties have been introduced: 1. Large; 2. Common or yellow; 3. Red or small brown; 4. Common small. This crop requires a dry warm soil, and might be advantageously grown in arid sandy situations unsuitable for common garden crops. It is very impatient of wet. The manner of sowing is to plant a row of beans between each row of lentils, in order to prevent their falling upon the ground, and to avoid the trouble of propping, which, however, would be the more advantageous method. The lentils should be sown in pretty thick rows at 18 inches or 2 feet apart. One plant produces from 100 to 150 pods, each pod containing two or three seeds or 'lentils,' which are smaller than tares, and may be cooked in the manner of peas.

Root Vegetables.

The vegetables grown for the sake of their roots are of two kinds—1. Those in which the roots are more or less round or lumpy, including the Jerusalem artichoke, the potato, and the turnip; and 2. Those which are tap or taper rooted, including the carrot, the beet-root, the radish, and the horse-radish. Strictly speaking, the tubers of potatoes, &c., are not *roots*, but merely concentrated stems of the vegetable below ground, the real roots being small fibres which shoot out from the tubers, and bring nourishment to the whole. All require depth of soil to penetrate, and also looseness and breadth of mould to allow of expansion.

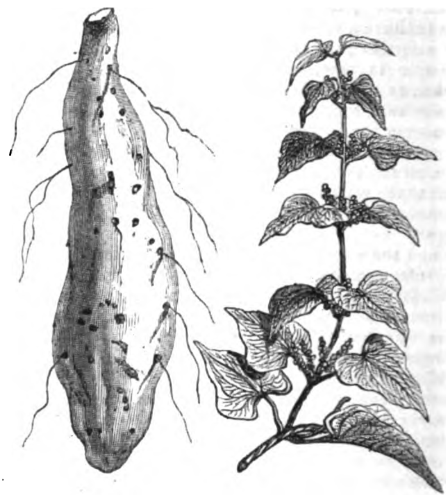
The Jerusalem Artichoke is a root which may be said to combine, in point of flavour, the turnip with the potato. Its name is an absurdity, for the plant has no resemblance to an artichoke; and the word *Jerusalem* is a corruption of the Italian name *Girasole*. The plant

is a native of Brazil, and botanically belongs to the same family as the sunflower, but it rarely produces flowers in the British Islands. The tubers, which alone are eaten, are produced abundantly under the surface, close to the base of the main stem. The plant is set like the potato, by either whole roots or cuts with one or more eyes to each. The pieces or cuts should be prepared at the time of planting, and set by depositing in shallow trenches two feet apart, and one foot asunder in the row; and being covered with earth, nothing more will be required but to keep the ground clean by the hoe. The season for planting is in the first dry weather of March; and half a peck of tubers, according to Abercrombie, will plant a row 120 feet long. A good mellow loam is the proper soil, and the spot for planting should be apart from the vegetable-garden, otherwise this prolific plant may intrude, and become a complete nuisance. Being set in March, the plant is perfected about October or November. Dig only when wanted, if that be convenient; but if there be a danger of frost, as will most likely be the case, lift the crop, and store away for winter use in moist sand or any kind of light soil through which the frost cannot penetrate. This excellent vegetable is but imperfectly appreciated in Scotland, and even in England.

The potato, like the Jerusalem artichoke and some other plants, is a naturalised exotic in English gardens from the wilds of America, and has been greatly improved by culture within the last hundred years. There are many varieties, individually distinguished by colour and flavour; and as some are better than others, it is very important that proper sorts should alone be cultivated. There are two distinct kinds—*early* and *late*. Early potatoes soon come to perfection, and cannot be stored for future use. On this account, as well as on account of the small amount of produce, they are rather grown as a luxury than as an important article of food for the cottager. The true potato is the late kind, which will store for winter and spring use. Of this there are hundreds of sorts, every district apparently having one which is best adapted to its soil and climate.

The potato may be cultivated either from seed procured from the apple on the stalk, or from the tuber itself. If from the seed, the first crops of tubers are only a little larger than peas, and several seasons are required to bring the plant to an edible size. The common method of cultivation is by pieces or cuts of the tuber, each having at least one well-defined eye; cuts with two eyes are generally preferred. These are set in trenches, the ground being in good heart with previous manuring, or good old manure placed in the bottom of the furrow along with the sets. The season for planting is late in April. Dig and plant sets, fresh cut as the work proceeds, placing the sets from nine to twelve inches apart, and the rows being about twenty inches asunder. Heap six inches of soil loosely over the sets, and when the shoots have risen sufficiently above ground, keep earthing them up with a hoe. When the stalks begin to decay in October, the crop is ready for lifting. Constant stirring of the soil, and earthing up, is the great point in potato culture. (For further information on potato culture, see AGRICULTURE.)

The Chinese Potato.—Under this name has recently been brought into notice a crop which may erelong acquire some importance, although the promises held out of its forming a complete substitute for the precarious potato crop are not likely to be fully realised. The new plant, like the East and West Indian yams, previously known, belongs to the genus Dioscorea (*D. Japonica* vel *D. Batatas*), and has been cultivated with sufficient success in Britain to shew its suitability to our climate. In China, it has been long known. The adjoining drawing shews the foliage and root of this plant; the latter is very long, and therefore requires a deep light soil. The French horticulturists believe that in point of flavour and nutritive properties, it is equal to the potato; that the yield is greater, whilst freedom from disease renders the crop more certain; that it will grow



Chinese Potato (*Dioscorea Japonica*).

upon sandy and poor soils; that it can be propagated with facility; that it may remain in the ground several years not only without degenerating, but, on the contrary, increasing in size, weight, and nutriment, 'furnishing at all seasons of the year an aliment within the reach of every one;' that when harvested, it may be preserved in cellars or sheds, without vegetating, for many months after the potato has become useless for food; and that it requires a shorter time in cooking than the potato, ten minutes boiling being sufficient. Our observations of the culture of this crop in Scotland during the two past seasons—1855 and 1856—lead to the conclusion that these advantages will not be so fully realised in northern countries as in the south of France; but the crop appears well worthy of continued attention as a valuable addition to our culinary plants. The system of cultivation, based on Dr Lindley's recommendations, is as follows: The smallest tubers are set apart for propagation, and pitted to guard against frost. In spring, they are planted in furrows, in well-prepared deeply dug ground in a warm situation; the young shoots soon appear, and may be made available for cuttings, if there is a scarcity of roots. The ground should be kept quite free from weeds by stirring of the soil, &c., during summer, so as to give the plants free exposure to the sun and air.

Of the Turnip there are many varieties; the leading ones grown in gardens are—the *early Dutch*, which is white; the *yellow Dutch; golden stone;* the *Swede; orange jelly;* and the *black turnip.* The white is the most delicate while young, but the yellow Swede is preferable as a keeping or late turnip. The yellow Dutch has also an excellent flavour. Turnips are cultivated from seed in drills one foot or more apart, and thinned when they come into leaf, to afford room for their expansion. For the two Dutch varieties, the best soil is sandy, enriched with bone-dust, guano, or good old stable-dung. Small sowings should be made in succession from March till July, and then the main crop for winter should be sown. Swedes should be sown in April and May. Deeply hoe the ridges after thinning, and keep the surface clear of weeds.

Of the Carrot, the favourite varieties are the *early horn*, the *Altringham*, and the *white Belgian.* All require a deep light soil. The early horn is sown in February for the spring crop; the other kinds are

sown in March, April, and May. All are sown broadcast in beds, and on a calm day, if possible, as the seeds are very light; they should also be rubbed between the hands, and mixed with some dry sand or wood-ashes, to separate them, and so facilitate an equable sowing. The seed may be saved by planting a few of the best carrots to stand the winter; seed will not retain its growing principle above a year, and therefore requires to be purchased with caution. Carrots may be stored like potatoes in winter; and it adds materially to their preservation in a sound and sweet condition, to riddle over the layers a few barrowfuls of dry mould or sand. The Altringham is best suited for a full garden crop; but all the varieties are in many soils subject to insect attacks.

The Parsnip is a taper-rooted vegetable, resembling the carrot in shape, and in England is a delicious vegetable. It is an excellent agricultural as well as horticultural crop, being extensively grown for cattle on the continent. It requires a rich deep soil, trenched and manured as if for a crop of carrots. The seed is sown in drills a foot asunder. The period of sowing is comprised between the last week of February and the first week of May. On thinning out, let the remaining plants be nine inches apart in the row. Parsnips are not liable, like carrots, to be injured by severe weather; but if taken up before Christmas, and properly protected, they will continue good till May in the following spring.

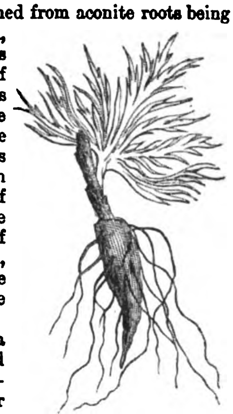
Of the Radish there are numerous varieties generally cultivated. According to Lindley's catalogue, these are— 1. The long white; 2. Purple or salad radish; 3. Salmon or rose-coloured; 4. Scarlet; 5. White Russian radish; 6. Crimson turnip-rooted; 7. Early white; 8. Purple turnip; 9. White turnip; 10. Yellow turnip; 11. Black Spanish; 12. Brown oblong; 13. Large purple; 14. Round brown; 15. White Spanish, a large bulb, which in good soil grows to the size of a small stubble turnip.

Numbers 2 and 3 are the best of the spindle-rooted radishes; numbers 6 and 7 of the early turnip-rooted. The winter black radishes are rarely seen in gardens; but the large white (15) is very mild, if the soil and season be favourable, and its texture is tender.

Sown in February and March, the spring radishes come into use in April and May; if required earlier, they must be protected by frames or mats. The market-gardeners obtain them early by gentle forcing, covering the beds every severe night. The sowings of all the early varieties may be repeated monthly till August. The winter radishes are sown in July and August, and come into use from September till the spring. A rich and light soil suits the radish, with occasional copious supplies of water; and rapidity of growth is required, otherwise the roots will not be tender, nor will the flavour be mild.

Spottiswoode's Rat-tail Radish.—In 1856, a remarkable kind of radish was raised in the Edinburgh Botanic Garden from seeds sent from India by Mrs Colonel Spottiswoode. It is called the Rat-tail Radish, and the edible part or 'radish' is not the root, but the seed-pod in a green state; when sown early, it produces a very abundant crop, and is well suited to the climate of Britain. The young plants require to be thinned out to a foot or more apart, in rows of about two feet, and plentifully supplied with water during dry weather. The radishes or pods of this plant are very delicate, and well adapted for salad.

Horse-radish is a plant which in most soils is of uncontrollably luxuriant growth: it is a most pernicious weed where it intrudes, on account of the multitude of vital germs with which its root-stock abounds, and by which it is rendered a sort of vegetative polypus, every inch of it being capable of developing a growing bud. The horse-radish is thus of very easy culture, but to be grown to perfection, requires a deep soil. It is ordinarily grown in an out-of-way shaded corner, and left without care, furnishing in this way an ample supply of roots. Serious accidents have happened from aconite roots being used instead of horse-radish, and therefore great caution is required. With the view of supplying instruction on this point, and preventing future accidents, specimens of the two roots have of late years been placed side by side in the botanical museums of Kew and Edinburgh, and we here represent the root of the poisonous aconite, which, it will be seen, is quite different from that of the horse-radish.



Root of Aconite, a poisonous plant, occasionally mistaken for horse-radish.

Beet-root.—The plant is a biennial; that is, it grows and perfects its roots in one season; in the following summer it sends up its flower-stalk, ripens its seeds, and dies. Of the two varieties of red beet, the smaller deep-purple variety is greatly preferable to the larger, which approaches to, and is little better than, mangel-wurzel. We select two varieties: 1. The short-rooted deep-purple beet, for its root; 2. The *Beta cycla*, or silver beet, the leaves of which only are used in lieu of spinach.

To grow the red beet well, the ground ought to be light and pulverisable, otherwise the spindle-root will be diverted if it meet with obstacles, and become forked and distorted. Trench the plot to the depth of eighteen inches, removing large stones, roots, and hard clods of earth; lay a stratum of manure at the bottom of the trench, in order to attract the root downward; then return the fine earth. Let the work be completed before frosts set in, and mark out the beds according to the number of rows required. At the middle or latter end of March, the seeds are to be sown. In sowing, stretch the line, and draw an even drill about an inch or an inch and a half deep, and drop the seed-vessels at even distances, two or three inches asunder; for although these spaces are much too small for final growth, it is in all cases wise to be liberal of seed, because insects and other enemies destroy many plants, and thus a season may be lost. Cover with light fine earth, and tread or beat the covering earth with the spade. If the plants rise equally, thin them gradually, till they stand from nine to twelve inches apart every way, or even eighteen inches for the large-rooted variety. Beet will transplant, but the operation dwarfs the plants; and at best it is attended with some risk. Keep the rows or beds entirely free from weeds by hand-weeding or flat-hoeing. Some roots will be ready in September, and thence throughout winter. In using them, or prior to storing up during winter, cut off the straggling leaves, being careful not to wound the roots; they keep well in dry and well-washed sand, but become tainted if wet straw or decomposable vegetable substances are present.

The Onion Tribe.

This savoury class of kitchen vegetables comprises the onion, leek, garlic, and shallot, the two former being by far the most important. All are natives of Eastern countries; but they grow to great perfection, as respects pungency of flavour, in the British Islands.

The Onion.—For a crop of onions, the soil should be rich, light, and deep, and well exposed to the sun. Before sowing, work and enrich the bed to the depth of eighteen inches, and then beat it flat and firm with a spade. Sow the seeds broadcast, at any time in March, or even so late as the beginning of April. Sift fine sandy earth over the seeds, and pat the surface even. As the onions advance, thin them out according to the variety. Keep the ground quite free from weeds. In September,

twist the necks, take up the crop when the leaves become yellow, and expose the onions to sun and air under a shed till they be externally quite dry. Many sow onions in drills, but space is lost by that method.

A summer supply of onions, at a time when the previous stock is exhausted, and the growing autumn crop has not come into season, must be desirable, and it is said to be easily obtained. Prepare the ground early in February; select a number of those small bulbs that are always found in every bed of the larger kinds, which are not above an inch broad. The bed being ready about the end of the first week, mark out squares on the surface by means of cross-strings, but do not move the ground. At each intersection of the lines, press in an onion, the root downward, to one-third of its depth, so that the bulb may remain firm and erect. Thus, when completed, the bed will exhibit the onions in squares five or six inches asunder. The onion forms its bulb in the first year of its growth, and the flower and seed in the second year. These small onions will therefore naturally attempt to produce a flower-head, which, as soon as it is fairly visible, is to be pinched off. Another attempt will be made, and that also must be frustrated. The natural course of the vital fructifying sap being thus interrupted, will be diverted to the bulb, and gradually, almost imperceptibly, two, three, or four onions of medium size will be produced and grow freely. These are to be taken, as soon as they are ripe—which, if the summer be fine and sunny, with occasional showers, will be in July—and dried in the open air as before directed.

The potato-onion is very valuable on account of the heavy crop it produces in this way. The tree-onion is also no less useful than curious.

The Leek, if properly treated in a favourable soil and situation, grows to a very large size. It is a plant which is much improved by proper transplantation, but yet can be grown very well in its seed-bed. The Musselburgh leek is the best. Sow the seeds in a shallow drill at the close of February or early in March, and cover them with half an inch of fine soil; as the plants grow, keep the surface clear of weeds by hand-picking and passing the Dutch hoe lightly on each side of the leeks. Presuming that they are thinned out at first to stand three inches asunder, half of the plants will remain, and the other half will be removed to another situation. Thus the plants in the seed-bed will stand six inches asunder, and will be greatly assisted if the ground be opened on each side of them at the distance of nine inches, and manured spit-deep. A crop of fine middle-sized leeks will thus be obtained in the succeeding autumn.

To transplant leeks, prepare a bed at the end of June, to contain either two or four rows, nine inches asunder, and manure the soil richly to the depth of a foot or fifteen inches. Let the bed settle during a week or more, and in July make holes along the intended lines six inches deep and as far apart. Collect a number of the strongest leeks, trim off the straggling roots, and all the suckers or offsets. Drop a small handful of powdery manure, or reduced year-old cow-dung, into each hole, place in it a leek, and holding it by one hand, fill the hole with water. The object is to fix the leek as in a case, to which it can adapt itself, and will fully occupy, becoming, under propitious circumstances, a plant of large size and of most excellent quality.

Garlic, one of the most pungent species of *Allium*, is increased by dividing the bulbs into cloves or smaller bulbs, and planting them in good sandy loam at any period between the middle of February and the end of April. Draw drills two inches deep, and ten inches apart, then press the root-end of each clove firmly into the earth till it stand erect; let the distance between each be six inches, and fill up the drills with fine sand. Keep the ground free from weeds, and when the leaves turn yellow—which usually happens about the end of July or the beginning of August—take up the bulbs with a trowel or handfork, and keep them in a dry room.

The Shallot is a native of Palestine; its culture is precisely the same as that of garlic, therefore both may be grown to great advantage by adopting the plan suggested by the late Mr Knight (*Trans. Lond. Hort. Soc.* ii.). Let a rich soil be placed beneath the roots, and raise the mould on each side to support them till they become firmly rooted. This is then removed by a hoe, and by pouring water from the rose of a watering-pot, till the bulb stand wholly out of the ground. Thus they become mere surface bulbs, supported entirely by the fibrous roots, which pass deeply beneath into the rich soil. The growth of these plants, Mr Knight adds, so closely resembled that of the onion, as not readily to be distinguished from it till the irregularity of form became conspicuous. 'The form of the bulbs, however, remained permanently different from all I had ever seen of the same species, being much more broad and less long; and the crop was so much better in quality, as well as more abundant, that I can confidently recommend the mode of culture to every gardener.' Shallots have a strong but not unpleasant odour, and are therefore generally preferred to the onion for various purposes of cookery, and for making high-flavoured soups and gravies.

Chives, one of the smallest of the garlic tribe, is a hardy and useful vegetable, far superior to young immature onions. The plant grows in tufts somewhat like small rushes in appearance, but of a colour resembling the yellow green of young onions; it never bulbs. A crop is readily increased by dividing the roots in April or early in May.

Salads.

Salads are those plants whose fresh leaves are eaten at table raw, or only dressed with zests and condiments without the preparation of cooking. The principal vegetable of this kind is

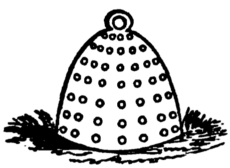
The Lettuce, of which there are several varieties, but all may be classed under two heads—the upright or cos lettuce, and the cabbage-lettuce. In spring culture, sow every month in very shallow drills of fresh-digged ground, in good heart, made rich with rotten manure. Strike the drills a foot asunder, and as the plants rise, thin them to stand in regular order, first to two inches, then, for table use as small salad, to six inches, and for the larger sorts, finally to one foot. With care they may, in moist weather, be safely transplanted during spring and summer. Spring and summer lettuces are sown from February to July. In September, two small sowings should be made of the hardy sorts, to come into use during late winter and spring; but it would be safer to make use of a large three-light frame. Some lettuces heart freely; those which do not, should be assisted by passing a string of bast round them from the middle upwards. This bandage must not remain many days, otherwise the plant will run to seed, and become bitter.

In autumn culture, sow in August, in drills pretty close together, for the express purpose of transplantation in September or October; they will not then run up. When the plants are three inches high, thin out half of them, and transplant some into warm quarters, and others under a frame; protect by coverings of hoop and mats those in the open ground; and if they bear the winter, thin the plants early in the spring to six inches apart. The plants in the frame will rarely fail if the earth be free from slugs.

Endive is a salad of a pleasant bitter taste. There are three principal sorts in ordinary cultivation—the *green-curled*, *white-curled*, and *Batavian*, with undivided flat leaves. The seeds are sown at different periods between the beginning of June and the second week of August, as required for the autumnal, winter, and spring crops. When the plants are three or four inches high, they may be removed to beds of moderately enriched

loam, to stand a foot apart. But transplantation is not essential, for very fine plants are produced in the seed-beds. When they are nearly full grown, they must be prepared for the table by blanching, as otherwise they would be too bitter for use.

Blanching may be effected by several methods: the most simple is that of passing a string of soft bast matting round the leaves of each plant, so as to exclude the light from the heart; but as hard frost is very injurious, some plants ought to be removed to a bed of dryish earth or sand under an airy shed; or a garden frame, partially covered, might be placed over a certain number of those already tied up. A good kind of pot for blanching is one of French invention, made of earthenware, and perforated with holes, as represented in the adjoining figure. Many persons blanch by only throwing straw loosely over the plants, but this makes a litter not very pleasing in a garden. The curled endives would blanch in a short time without tying within a darkened frame or pot, and be thus less liable to decay; for it is known that the plants suffer from being tied. The Batavian endive, however, requires a bandage at all times, otherwise its harsh green leaves will be useless, and the central heart, which alone is edible, will never be rendered tender and white. Some persons blanch in a simple way by laying a tile over the open heart of the vegetable.



Garden-cress.—In alluding to the culture of this common salad, we will include *mustard*, because they naturally are companions, and are often grown together. In cultivating mustard and cress, it is essential only to remark, that the latter should be sown three or four days in advance of the former, because cress is more tardy than mustard. Both are very accommodating herbs, inasmuch as they will grow upon wetted flannel in a saucer placed in any apartment, as well as on the floor of a green-house. On shipboard, under cover, they can thus be obtained throughout the winter; and in the garden from March to November, by successional sowings made once every fortnight. Sow either broadcast over the surface of a fresh-digged bed, raking and patting in the seeds by the flat of the spade, or in shallow drills half an inch deep, covering the seeds with a little fine soil. Sow thickly; and if the young plants rise, as they are apt to do, with a covering or cake of earth over them, remove it by means of a light heath-whisk. This salad should be taken before the true rough leaves be fully developed, a precaution which is often neglected in Scotch gardens, hence the want of appreciation of this salad.

Water-cress, a native plant, is grown to most advantage by the edge of running streams.

Celery is a native of Britain, found in ditches and marshes near the sea. The odour of the wild plant is very rank and disagreeable, and its juice is acrid and dangerous. By cultivation, this dangerous weed has been brought to the condition of that highly esteemed vegetable which is called sweet-celery. Of this there are many varieties—the common upright hollow white celery; the purple-stalked; the giant white and red; solid; Goodall's white, &c. Celery may be sown in a frame, with gentle heat, at the end of February, for the first crop, and thence to the end of May, on a warm sheltered border for succession. All the seedling plants should be pricked out into intermediate beds of soft rich earth—the first sowings over a gentle hotbed—to bring strong transplants in June and July.

The roots of celery become bushy, and its leaf-stalk firm and stout; it likes moisture, and the soil to be rich with decomposed vegetable matter. Self-sown seed, that which falls from a seedling plant, if it light on rich earth, as that of a newly dressed asparagus-bed, in October, will bring noble plants in the spring, fit to go at once into trenches. If produced by autumn-sown seed, nothing more is required; but the spring-sowings will always furnish weak and lax plants, that, when grown three inches high, must be removed to a nursery-bed over manure to strengthen and become stocky. Few kitchen-gardeners can obtain these plants till June, unless grown constantly under glass.

To trench for celery, prepare the trenches by previously manuring the whole plot; and after the ground has settled, dig a trench or two for the first plants a moderate spade's depth, depositing the earth on a ridge to the right and left of the trench. Clear the bottom, lay on it three inches of leafy manure, and re-dig the ground, to incorporate it with the manure. Then select a number of the strongest and most regular plants, trim off loose straggling fibres, and all the side-suckers, but do not touch a true leaf: set the plants four or five inches, and the large sorts six inches, asunder, and fill the holes with water; shade during sunshine for three days, and give water every evening, unless there be copious showers. The size of the young plants will indicate the season for transplanting.

As to future attention, water the plants frequently in the evenings till they begin to grow; and when they become three inches higher, stretch a line along each edge of the trench, and cut down by the spade as much soil as will suffice to earth the stems to that height; break it fine, and grasping each plant firmly in the left hand, insinuate the soft soil around it; then place a little finely reduced manure along the channel of the trench on each side, remote from the stems; this will nourish the fibres, without coming into contact with the leaves; water poured once or twice along the course of this manure will promote its action. Repeat the earthings as often as the plants advance three inches, and manure the extreme edges where the spade has made a groove, till at length the trenches become level with the surface of the ground. Then dig out soil, and add it, sloping ridgewise, till the plants are 'landed' up fifteen, eighteen, or more inches above the surface level. Celery may be preserved from frost by boards placed as a pent-house over the leaves.

Celeriac, or turnip-rooted celery, is raised and nursed in the same way as celery; but in planting out, the ground is dug and enriched, not trenched, and the plants are set by the dibble or garden trowel along the course of shallow drills drawn by the hoe, six inches apart, watering them freely. As the growth advances, bring earth to the plants, by which the knobby roots will be blanched, and made delicate and tender. When these are the size of small turnips, they are fit for the table. Celeriac is never eaten raw as common celery, but is boiled, and served up with melted butter. The seeds of both the species ripen freely in the summer of the second year, and many fine plants are obtained from self-sown seeds, which may serve as excellent substitutes should the spring-sowings fail.

Sweet Herbs.

Rosemary and *Lavender* are hardy undershrubs, natives of the south of Europe. They yield powerful essential oils when distilled with water, that of lavender being employed, as are also the dried flowers, in the preparation of the spirit called *lavender-water*. Bees are extremely partial to the flowers of rosemary. Both these plants are propagated with great facility by slips of the young side-shoots, trimmed of the strip of ragged bark, and merely dibbled into the soil. They will grow almost anywhere, and in any aspect; but the flowers possess the highest degree of fragrance when the plants grow in a dry, sandy, or gravelly earth. Spring or September is most favourable for propagation by slips.

Thyme and *Lemon-thyme* are used in seasonings; the latter is one of the most fragrant herbs of the garden; both are raised from seeds sown early in spring, or by

opening the earth around the stems, spreading the reclining shoots like layers upon it, and strewing some fresh sandy mould over them. Roots are soon formed, and thus a supply of young plants is obtained. It appears essential to renew thyme, and to place it—lemon-thyme particularly—in new soil, otherwise the plant dwindles and perishes. A dry and rather poor soil seems most favourable to the growth and fragrance of thyme, which may be economically grown as a border.

Sage, red and green, is propagated in the same way as lavender.

Of Marjoram there are three sorts—*pot marjoram*, *sweet* or *knotted marjoram*, and *winter marjoram*—all hardy or sub-hardy perennial and biennial small shrubs, natives of the south of Europe, which grow readily in a dry light soil, but require change of situation. The first and third sorts may be propagated by division, in the manner of thyme, but the sweet marjoram should be raised from seeds sown in April every year, the plants to be thinned out to the distance of six inches. The flowers are gathered usually in July.

Savory.—Winter and summer savory; the former is propagated either by slips and cuttings, by separating the lower shoots, or rooted offsets, in spring; the latter is an annual, sown in April, and becoming fit for gathering in the summer and autumn.

Mint.—Spear or garden mint, and peppermint, are not properly sweet herbs; the latter, indeed, is only used medicinally, the essential oil possessing pungent qualities. Spear, or garden mint, is used in the kitchen for a variety of purposes familiarly known. All the species, including *pennyroyal*, another medicinal mint, are cultivated by division of the roots in spring. Mint delights in moisture, and extends with great rapidity. Care, however, is required to give it a new situation when the plant becomes weak, and its leaves appear of a pale and yellowish hue.

To dry and preserve these herbs, select the shoots just as the flowers form and shew colour, but before they expand; suspend them in an airy situation, under cover, not exposed to the sun.

Miscellaneous Vegetables.

Artichoke, though esteemed by many, yet is found in few gardens; it is a native of the south of Europe, and was brought to England nearly three hundred years ago. Two varieties of it are cultivated in the best gardens. The plant has fibrous, rather fleshy roots, large deeply cut leaves, whitish with down, and it produces an upright stem, bearing at the summit an oval or roundish flower-head, not unlike a thistle. Artichokes can be raised from seed, but much more speedily by offset-suckers, which are produced freely by the parent plant. Select a spot of open ground; any soil will do, but a free light loam is to be preferred. Dig out a trench two feet wide, and of the same depth, if the good soil extend so low; if not—and this remark will apply to every future allusion to trenching—remove all the good soil, whatever its depth, to a space beyond the boundary of the furthest intended trench, and dig and turn the inferior bottom soil, incorporating with it three or four inches of good half-decayed stable manure. Then mark out another two-feet trench, and throw into the first, eight or nine inches of the surface-soil of the second trench; add another similar layer of dung, and work it and the earth thoroughly together. Again, throw in the remainder of the good soil of trench 2, and add a third layer of manure, which mix also with the soil. Thus trench 1 will be completed; and by repeating the work till the earth dug out of 1 be deposited in the last-intended trench, all will be manured and laboured alike; and a piece of rich ground will be prepared that may be expected to keep in heart during many years. The work ought to be performed before frost sets in; and if the land be heavy, it will be prudent to set it up in ridges.

Suckers are generally ready in April; and gardeners are willing enough to part with them. Having procured the desired number, level the ground, dig a portion of it again, and reduce the surface to the finest condition possible; then, after trimming off decayed leaves and damaged roots, plant the suckers in a row, two feet asunder. It is usual to form a complete bed of three or more rows, five feet apart—and we have prepared ground, as above, for such a bed—but some think that artichokes and other permanent vegetables ought to be set in single rows ten feet apart, because the ground between the rows can be cropped with other annual vegetables, which will benefit the artichoke, by the rich manure applied at the first and other successional croppings. The garden, in all its crops, permanent or temporary, ought to be made a laboratory of corrective rotations, wherein one crop shall attract and consume that which has been left by another. A dozen good artichokes will be sufficient for a moderate family; but as some suckers may fail, it will be prudent to set the plants one foot asunder, securing the roots firmly in the soil, and giving a copious watering at the time of planting, the supernumeraries can be removed when all are safe.

The subsequent culture is as follows: Hoe occasionally to destroy weeds, and keep the surface open. A crop cannot be anticipated during the first year; and if little heads be pushed up, it will be wise to remove them as soon as seen. When the plants become torpid and yellow in autumn, a few of the outside leaves are to be scaled off by the hand; the ground should then be marked by the line on each side at eighteen inches' distance from the plants; and being cut straight by driving the spade to its full depth along the line, the earth is to be dug up, broken fine, and laid on the surface of the eighteen inches left on each side of the plants, bringing it carefully against them, so as not to fall into their hearts, but yet to protect them effectually near the tops of the leaves; the operation is called *landing up*. This done, fill the trenches with stable litter, straw, dung, or fern; and in the event of hard frost, bring more litter close to the plants, and lay it over the *landing* earth, for artichokes are rather tender, and may be destroyed during severe winters. This practice is to be observed every year, with the additional precaution to cut the flower-stems close down.

Spring-dressing consists in removing suckers after levelling the earth, and digging in a little of the short manure that is left on the ground after clearing away the straw, &c., and making the soil neat. One or two of the strongest suckers may be left on the stock.

Asparagus is justly esteemed one of the choicest vegetables of the garden; and indeed it possesses every quality to recommend it—flavour for the palate, hardihood of constitution, facility of culture, and it brings profit to the grower. It is a native of the British Isles, but in its wild state bears little resemblance to the plant in a state of cultivation. Perfectly hardy, so much so as to resist a frost below zero, it nevertheless benefits by protection and generous tillage. In forming new plantations, it is customary to purchase two-years' old plants, because they are safely removed at that age, and will come into bearing in two years more. April is the best season for planting; but having ourselves produced beds from *seeds*, we prefer that method of propagation. Let the ground be prepared before frost sets in by deep trenching and rich manuring; but by all means adopt the practice recommended by Grayson, who produced what he styled *giant asparagus* about the year 1830. We give his own concise directions in the following quotation: 'If your ground be stiff and unpleasant to work, get some milder earth to mix with it, and a very large cart-load of rotten dung to about every ten square feet; trench it two spit deep, and loosen the bottom; let the dung and earth be well mixed together. When your land is fit for planting, draw your drills six inches deep, and sixteen inches from the first row to the second; that will form

a bed; and ten inches between each plant in the row. Do not raise your beds till they have been planted one year; then put on about four inches of mould out of the alleys, and cut till the 10th of May. If you keep them well manured, they will last twenty years; but *never cut later than the 4th of June.* Let them be eight feet in the clear from bed to bed, so that you may crop between, and lose no land.'

Here we find the sum of all that constitutes asparagus planting; but after all, persons must be content with such plants as the constitution of their ground will produce: for this very sort, which in the rich alluvium of the Thames produces shoots an inch in diameter, dwindles in the loams of ordinary gardens to less than half that size. Nevertheless, if the beds be narrow, thoroughly manured at first, remote from each other; if, also, about February of the first year after planting, a trench, eighteen inches deep and a foot wide, be formed on each side of the narrow bed, and twelve inches distant from the plants, and be half filled with the best rotten dung, incorporated with an equal quantity of the earth dug out; a most excellent asparagus will be obtained speedily, and the quality will not deteriorate. This enrichment may be occasionally renewed, but these auxiliary trenches are to be made at an increased distance each time, so as to avoid cutting and mutilating the roots, which extend very rapidly. Saline applications prove of great benefit to asparagus.

The seed of asparagus may be purchased, but it is yielded abundantly by every good bed, and should be gathered before it falls off, and kept in the berry till spring. We will presume the object to be double—first, to raise bearing-beds; and, second, to raise a stock of young plants for forcing. In the former case, the ground is to be in readiness for narrow beds, eight feet asunder; in the latter, wide beds, like those directed for artichokes, should be made. Towards the latter end of March, rub out the seed, and place the line along the course of the bed; strike two drills with the hoe at the distances directed by Grayson, two inches deep; or in the broad beds make similar drills nine inches asunder; and in both scatter the seeds pretty thickly, say half an inch apart; cover with fine earth, and pat it to a smooth surface with the spade. Watch the coming up of the plants, and be prepared to dust them with air-slaked lime, if slugs threaten them. When they shall have fairly formed rows of young seedlings six inches high, thin out the *narrow beds* first to four inches apart, and again to nine inches. The *seed-rows* for forcing, thin first to three, and afterwards to five inches, and then leave both to grow, observing to use the hoe repeatedly to keep down weeds.

In future treatment, when the stems become yellow, cut them down at two inches above the soil; clear the surface with hoe and rake, and lay on the beds eight inches of decayed leaves. This surface-manuring, which will generally take place about the end of October, will tend greatly to protect the young plants, and impart a stimulating principle to the ground; so that in early spring the plants will be strongly excited, and rise through the remaining manure in perfect safety. The trench-manuring, also, before alluded to, will come in aid of the top-dressing. We have cut excellent 'grass' within three full years of the sowing, and still reap profitable crops from beds twelve years old. These annual enrichments, be it observed, might be persisted in with every bed that is used for cutting; but for the beds devoted to raising plants for forcing, it will suffice to make the ground thoroughly rich at the time of trenching; because the plants, when three or four years old, will be removed to the forcing department; yet a coating of half-decayed leaves or manure, after the stalks are cleared off, will not be lost, as the stronger the plants, the more remunerative will be the produce.

When once asparagus is in full bearing, if the cuttings be judiciously made—that is, by taking only the strong shoots, always leaving one or two of medium strength to each crown, and duly applying manure—a bed may keep in high condition for twenty years. But it must not be forgotten that if every shoot be taken off a crown, to the end of a long season, that root will be destroyed. To prevent the crowns from being too deeply buried, in consequence of the autumnal dressings, it is customary to fork the beds late in March, digging them carefully, or rather loosening the surface with a fork of three prongs, and raking the rough earth into the alleys; this operation also gives freedom to the plant by opening the soil.

With respect to forcing, it is very easy with narrow distant beds to bring the plants somewhat more forward in the spring, by digging trenches eighteen inches wide, or wider, and above a foot deep, and filling them with warm stable-dung, blended with a third part of forest-tree leaves, raising the dung to six inches above the surface-level. The gentle warmth communicated will stimulate vegetation, and it would be assisted by covering the beds with hoops and mats, or with boards set up ridgewise, in the event of sharp frosty nights. Successional forcing-beds are prepared as soon as the cutting of the earlier begins to decline, or even when it is at its height.

The Cucumber and *Melon* are somewhat delicate in growth, and require a fine climate and extremely rich soil. The cucumber is usually grown over a heap of old horse-dung, on a spot of ground open to the south, and large enough to permit a two or three light frame to rest upon it. Dig out the soil a foot in depth, and lay it on one side, or around the trench. If this soil be a light friable loam, incorporate it, a month before it is to be used, with one-third part of leaf or vegetable earth and old decayed dung, and again dig this mixed earth two or three times. But if the soil produced from four or five year-old couch-grass roots, harrowed from a field of sound loam, can be procured, it is the best aliment for the cucumber. The soil should be ready in April, and the work of planting begun in the first week of May, by filling the excavation with stable manure to the height of a foot above the surface-level of the unmoved earth, and placing on it the frame and lights. In a week, the manure will have settled, and is then to be covered with a six-inch layer of the couch-mould or other soil, and a hill of dryish earth, raised a few inches higher, under each light, in which eight or ten seeds of any approved variety may be sown. If preferred, the seeds may be prepared by previous sowing, in pots in a slight hotbed, and the plants so raised can be transferred to the hills. But as the plan now recommended is not one of forcing, it is safer to begin on the spot by sowing seed and covering the bed with the lights, and those with mats or boards every night.

As the plants rise, observe them carefully, and pick out the central buds when the true leaves have become strong. 'When the plants shoot forth after a second stopping above the second joint of the laterals, produced by the first, they seldom miss to shew fruit at every joint, and also a tendril, and between this tendril and the shewing fruit there may be clearly seen the rudiment of another shoot. This shoot is then in embryo, but if developed, it becomes a fruitful lateral. And when the leading shoot has extended itself fairly past the shewing fruit, then with the finger and thumb pinch it and the tendril off just before the shewing fruit, being careful that, in pinching off the tendril and the shoot, the shewing fruit be not injured. This stopping of the leading shoot stops the juices of the plant, and enables the next shoot—the rudiment above mentioned—to push vigorously, and the fruit thereby also receives benefit.' (M'Phail.) These remarks will also apply to the melon, which, however, requires more heat and more careful attention. The cultivation of these plants is, in fact, frequently carried on together either in the same or in separate frames; and after the few remarks which

follow on forcing, nothing further need be said of the cultivation of melons.

Whether cucumber and melon plants have been raised separately in pots, or from seeds sown in the frame, they ought to be progressing early in June, and should be stopped occasionally, till fruit begin to shew itself. The soil must never be *wet*, but always retained in a free and rather moist condition, water being kept in the frame for the express purpose. No water ought to be poured against the stems—it should be applied to the soil around the slope of the hills only. Air ought to be admitted on all warm days, by tilting the back of the lights till three o'clock; but after that hour, the frame should be kept closed. When fruit is visible, stopping according to M'Phail's direction, should be persevered in, and its fertilising effects will soon be apparent. Cover with mats, and boards over them, at sunset. Every decayed leaf and weak shoot should be removed as soon as perceived.

In order to raise and fruit cucumbers or melons before midsummer, *forcing* must be employed. The hotbeds of the best regulated gardens are conducted without masses of manure under the roots; heat is obtained by means of hot-water tanks, thus manure is economised. By this method, cucumbers and melons can be produced during the spring and summer months with certainty and precision. In the cultivation of both these plants, equability of heat is important; and nothing would be more likely to secure this, and also to ward off sudden accession of cold, than to case the frame with an inner lining of thin boards, leaving a space of an inch or two between, to be filled with some imperfectly conducting substance, such as powdered charcoal or dry saw-dust, and taking care to secure it from the ingress of water. The expense would be trifling, and the security afforded very great.

Nasturtium, or Indian-cress (*Tropæolum majus*), is a native of South America, but is not tender. Although chiefly grown as an ornamental annual, the green seed-vessels are used as a pickle. These, when they ripen, separate and drop on the ground, where they remain torpid till the spring. It therefore requires no minute directions; and any one who once possesses a plant, can multiply it by sowing seed in any way or place which may suit his taste. It may be sown with safety from the middle of March to the middle of May.

Parsley.—Several kinds of parsley are in cultivation; these are the plain and curled-leaved, and the common and the broad-leaved, or Hamburg parsley. Preference ought to be given to the curled-leaved parsley. This vegetable is one of the most easily cultivated, and it will long keep the ground with little trouble. It is sown in drills—generally in March—in any spare patches of border, lies long in the ground before springing, and arrives at maturity the next season. When it has attained this state, it may be cut when required; even during a long winter-storm, if the precaution has been taken to cover a drill or two with peas-stakes or other close wattling. It should not be allowed to go to seed, but kept well cut down.

Rhubarb is a large vegetable, grown for the sake of its firm leaf-stalks. The leaves are very broad and spreading, to catch moisture, and shelter the ground around the main-stem from the exhausting heat of the sun. When once planted, it requires no trouble, but keeps growing till the plant runs up to seed. To give additional size to the stems, cut off the seed-stalk. Suckers taken from known and approved plants succeed well, but the plant can easily be raised from seed. Each plant requires considerable space; and in preparing a plantation of rhubarb, the soil should be thoroughly worked to a great depth. In taking away the stalks for use, do not cut them, but wrench them from the main stock, so as to take them out by the socket. The variety called Victoria Rhubarb is the one generally chosen as the best and most productive. Rhubarb may be forced by very simple means. A common method is to cover it in the early part of the year with a box, to which air is admitted, and covered with a little stable manure. This blanches as well as brings forward the stalks; but that is an advantage, as it renders the vegetable more tender and delicate in flavour. Some bring forward rhubarb in pots in darkened forcing-houses, and for this purpose plants two years old are most suitable. Watering copiously is necessary in the early stages of growth, whether in the open air or under boxes. As rhubarb forms a valuable vegetable for tarts in spring, before gooseberries are ready, it would not be misspent time or trouble for a cottager to attempt forcing by the simple means above recommended. A well-planted plot of rhubarb, according to Mr Paterson, will continue productive for seven years; but a new one should be made a year or two before removing the old, and in the meantime, some light crop may be raised on the new ground, which is but thinly occupied by the young plants.

Sea-kale is a perennial vegetable, deriving its name from being found growing in a wild state on the sandy downs which border the southern coasts of England. The method of garden culture is as follows: Beds or spaces for single rows should be trenched and prepared as for asparagus; and at any dry period of March, when the surface-earth will work freely, one or more drills should be drawn by the line, two inches deep, and the seeds scattered along the drill; or five or six seeds should be inserted at distances of two feet apart. The seeds are then covered with earth, and when the plants become strong, they are to be thinned of supernumeraries, leaving one or two of the strongest remaining, eighteen inches or two feet asunder every way. If the plants be weak, it will be prudent to retain double the number. During the first season, nothing more will be required than to keep the bed or row free of weeds. In the following spring, if the plants stand nearer to each other than eighteen inches, the surplus number should be carefully raised, and transferred to another prepared space, planting the crowns of the roots two inches below the surface. Eighteen inches to two feet, according to the strength of the plants, may be the regular distances at which they are to remain. The first bed, if pots be placed over the crowns, will yield a moderate supply of blanched kale during April or May of the second spring.

Sea-kale may be forced at various periods, commencing with November, by inverting large pots over the plants, and covering those with warm dung, or dung and leaves, to excite and maintain a heat in the pot and soil of about 55° Fahrenheit. Sea-kale, like other plants subjected to heat, can be made to conform to induced habits. Thus at first it seems to remain long torpid, even though the heat be considerable; but after a second season, provided the gardener be himself regular, the plants will yield to the stimulant almost to a day, though it be comparatively mild; hence sea-kale is at command from December to March by heat, and then the succession can be maintained during April and part of May by the cold beds or rows. 'You may have excellent sea-kale,' says the author of the *Manse Garden*, 'in April from drills ridged up with earth; in which case every pair of drills must have greater distance for the convenience of mounding, and the plants may be so much closer in the bed. Straw in contact with the plants is unsuitable to blanching, as it communicates a bad flavour; but raked leaves do well, perhaps fern, sand certainly. Where the plant grows wild, as it does by the sea-shore in several parts of England, it is gathered in the finest condition when whitened by the sand, which the wind piles gently over its head in the manner of a snow-wreath.' As soon as the kale is cut from one or more roots, a sharp spade should be thrust through it, so as to cut the plant level with the surface.

Spinach is an annual of which there are two principal kinds: the round-leaved, smooth-seeded, which is sown chiefly for spring and summer crops; the triangular-

leaved, prickly-seeded, or winter spinach. The round-leaved should be sown about the end of January, and again in February and March, for successive spring and summer crops. The triangular-leaved is to be sown at the end of July or first week of August, and the leaves come into use at the beginning of winter; the plants require thinning and hoeing, and may be transplanted. The outer leaves only are to be taken during winter and spring, the inner leaves forming in their turn an ample succession. The seed or flower-stalks will become apparent in the early part of the summer, and some of the best plants, male and female—for spinach produces both separately—should be left to perfect the seeds. Plants designed for seed should be thinned to the distance of eight or ten inches. Spinach may be raised in any common garden-soil; but the more that soil has been previously enriched with dung, the better; and for either winter or summer spinach, it is hardly possible to manure the ground too highly, for succulency adds greatly to the value of this vegetable. Liquid manure proves effective. Always select an open situation, not too near low-spreading trees, &c.; as in close and shady places it is mostly drawn up weak, and soon runs to seed, without attaining perfection. A kind of wild-spinach is not uncommon in Britain (*Chenopodium Bonus-Henricus*); but it is inferior in succulency to the garden sort, and more bitter.

Vegetable marrow is a species of gourd (*Cucurbita*), the pulp of which, from its richness and flavour, has been called *marrow*. It was brought originally from Persia, and was particularly noticed by Mr Sabine, in the *Horticultural Transactions*, vol. ii., where he described the best culinary variety as bearing a 'fruit of uniform pale-yellow or light-sulphur colour; when full grown, about nine inches in length, four inches in diameter, of an elliptic shape, the surface being rendered slightly uneven by irregular longitudinal ribs, the terminations of which uniting, form a projecting apex at the end of the fruit, which is very unusual in this tribe.' There are other varieties which produce fruit that weighs twenty or thirty pounds, oblong in figure, and quite green during growth; such fruit, however, is coarse in flavour, and in no respect equal to the small cream-coloured variety. Attention has recently been called by Professor Lindley to the probable benefits to be derived from the increased cultivation of vegetable marrows and other gourds (*Gardeners' Chronicle*, 1856), which have never been much prized in Britain.

Sow in pots of any light soil early in April, treating the plants exactly as cucumbers under glass. About the middle of May, transfer them to a bed of rich earth over a trench filled with warm stable-dung. Protect the plants by a hand-glass or frame, which, if the shoots are to run on the ground, should be raised by four or more bricks, giving air freely. When danger of frost ceases, remove the light or frame.

We have seen the best plants nailed and secured to a wall, as trees usually are. They bear profusely in summer and autumn, and are not subject to be injured by damp. The seeds are sown on the spot at the end of May, and one strong plant remains, being stopped once or twice at the tips of the advancing shoots, of which six are enough for each plant. It would be wise to place a large spare light or two sloping in front till midsummer, and again early in September. If it be desirable to save seed, preserve the fruit first formed on a plant reserved for the purpose.

Mushrooms.—We have great hesitation in saying anything of the artificial growth of this delicious vegetable, both on account of the difficulty which unprofessional gardeners labour under respecting the right sorts, and the complex methods which require to be employed for bringing forward crops. The greater number of mushrooms brought to market are of natural growth on old rich pastures; and it would appear that, without providing a similar kind of soil full of decaying matter, the plants cannot be raised. The method of procedure is very peculiar. The mushrooms are not sown in the form of seeds, for they have no observable seeds, but by spawn, or portions of their substance, mingled in the prepared soil. Mr Rogers describes the process of mushroom-culture as follows: 'In June or July take any quantity of fresh horse-droppings—the more dry and high fed the better—mixed with short litter, one-third of cow's dung, and a good portion of mould of a loamy nature; cement them well together, and mash the whole into a thin compost, and spread it on the floor of an open shed, to remain till it becomes firm enough to be formed into flat square bricks; which done, set them on an edge, and frequently turn them till half dry; then with a dibble make two or three holes in each brick, and insert in each hole a piece of good old spawn, about the size of a common walnut. The bricks should then be left till they are dry. This being completed, level the surface of a piece of ground, under cover, three feet wide, and of sufficient length to receive the bricks, on which lay a bottom of dry horse-dung, six inches thick; then form a pile, by placing the bricks in rows, one upon another, with the spawn-side uppermost, till the pile is three feet high; next cover it with a small portion of warm horse-dung, sufficient in quantity to diffuse a gentle glow of heat through the whole. When the spawn has spread itself through every part of the bricks, the process is ended, and the bricks may then be laid up in a dry place for use. Mushroom spawn, made according to this direction, will preserve its vegetative power many years if well dried before it is laid up; but if moist, it will grow and exhaust itself. The next subject to be treated of is the preparation of the dung for the bed; and for this purpose, none answers so well as that of the horse, when taken fresh from the stable, and without an admixture of straw, hay, or other litter.

'About Michaelmas is the general season for making mushroom-beds, though this may be done all the year round. A quantity of the dung mentioned should be collected, and thrown together in a heap to ferment and acquire heat; and as this heat generally proves too violent at first, it should, previously to making the bed, be reduced to a proper temperature by frequently turning it in the course of a fortnight or three weeks; which time it will most likely require for all the parts to get into an even state of fermentation. During the above time, should it be showery weather, the heap will require some sort of temporary protection, by covering it with litter or such-like, as too much wet would soon deaden its fermenting quality. The like caution should be attended to in making the bed, and after finishing it. As soon as it is observed that the fiery heat and rank steam of the dung are gone off, a dry and sheltered spot of ground should be chosen on which to make the bed. The place being determined on, a space should be marked out five feet broad, and the length—running north and south—should be according to the quantity of mushrooms likely to be required. If for a moderate family, a bed twelve or fourteen feet long will be found—if it takes well—to produce a good supply of mushrooms for some months, provided proper attention be paid to the covering.

'On the space marked for making the bed, a trench should be thrown out, about six inches deep; the mould may be laid regularly at the side, and if good, it will do for earthing the bed hereafter; otherwise, if brought from a distance, that of a more loamy than a sandy nature will be best. Either in the trench, or upon the surface, there should be laid about four inches of good dung, not too short, for forming the bottom of the bed; then lay on the prepared dung a few inches thick regularly over the surface, beating it as regularly down with the fork; continue thus, gradually drawing in the sides to the height of five feet, until it narrows to the top like the ridge of a house. In that state it may

remain for ten days or a fortnight, during which time the heat should be examined towards the middle of the bed, by thrusting some small sharp sticks down in three or four places; and when found of a gentle heat—not hot—the bed may be spawned, for which purpose the spawn bricks should be broken regularly into pieces about an inch and a half or two inches square, beginning within six inches of the bottom of the bed, and in lines about eight inches apart; the same distance will also do for the pieces of spawn, which, in a dung-ridge, are best put in by one hand, raising the dung up a few inches, whilst with the other the spawn can be laid in and covered at the same time. After spawning the bed, if it is found to be in that regular state of heat before mentioned, it may be earthed. After the surface is levelled with the back of the spade, there should be laid on two inches of mould—that out of the trench, if dry and good, will do. After having been laid on, it is to be beaten closely together, and when the whole is finished, the bed must be covered about a foot thick with good oat-straw, over which should be laid mats, for the double purpose of keeping the bed dry and of securing the covering from being blown off. In the course of two or three days, the bed should be examined; and if it is considered that the heat is likely to increase, the covering must be diminished for a few days, which is better than taking it entirely off. In about a month or five weeks—but frequently within the former time, if the bed is in a high state of cultivation—mushrooms will most likely make their appearance, and in the course of eight-and-forty hours afterwards they will have grown to a sufficient size for use; in which case the author recommends that, instead of cutting them off close to the ground, they be drawn out with a gentle twist—the gatherer filling up the cavity with a little fine mould, gently pressed in level with the bed.'

The method above described is intended for open-air culture; but in large gardens, a mushroom-house is usually chosen, the beds being formed in large shallow boxes, arranged in the manner of shelves around the walls. Light is not required; and mushrooms may be abundantly produced in a dark cellar or outhouse, provided suitable materials are obtained, and care bestowed in regulating the temperature and maintaining a moist atmosphere. About two years ago, Lord Murray introduced the system of growing mushrooms in sunlight, and the experiments with his mushroom-house in the Experimental Garden, Edinburgh, shew that this method is an excellent one.

HORTICULTURAL MONTHLY CALENDAR.

Having in almost every instance mentioned the seasons for sowing, planting, transplanting, and otherwise attending to the culture of vegetables in the kitchen-garden, it would only be waste of room to repeat directions, as is usually done, in connection with the different months. It is hoped, therefore, that the following general references to the months will be sufficient:

January.—Trench and delve up all open grounds, if the weather permit; and in warm exposures, sow early peas and other articles that are to be brought forward early.

February.—Continue turning up the ground designed for early crops; sowing may go on a little more briskly, especially in warm and well-sheltered borders.

March.—This is a particularly busy month, being, from its open and drying character, favourable for all works of preparation. Peas, beans, asparagus, onions, carrots, &c., are sown; and various articles are transplanted from frames.

April.—A continuance of preparing, sowing, and planting; hoeing, thinning, and clearing out of weeds require also to be attended to. In very dry weather, seedling-beds should be carefully watered.

May.—The main crops are now to be sown, early peas earthed up and staked, and young plants transplanted.

June.—Sow kidney-beans, runners, &c.; water growing plants, if required; hoe potatoes, cabbages, and peas; and thin out beds. Gather medicinal and sweet herbs, when in bloom, and dry in the shade for winter use.

July.—Sow broccoli for the last time; also turnips, lettuces, &c.; and prepare all the unoccupied plots of ground for autumn and winter crops.

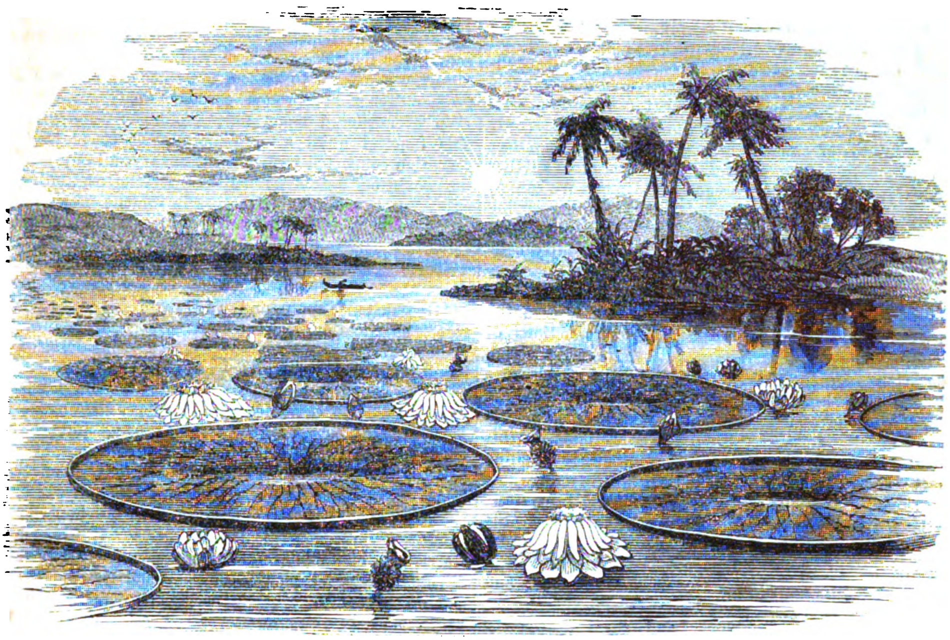
August.—Commence now to sow for the crops of next year, such as onions, early cabbages, and parsley; also winter spinach. Earth celery; hoe and thin turnips; cut down stems of gathered artichokes, and generally clear out all stumps and stalks of used plants, for their continuance exhausts the ground to no proper purpose. Cut herbs and gather all bulbous crops, such as onions, as soon as they are withered in the stem.

September.—The kitchen-gardener has now got his principal labours in cropping over, and his chief work is continuing to sow for winter and spring successions; he also digs potatoes that seem ready, and takes care to cut down and clear off weeds.

October.—The garden having been prepared for spring vegetables, sow what was left over last month, including celery, asparagus, also early peas and beans. The cabbages and savoys require to be earthed up as high as the leaves. Remove carrots and other roots, and store them away for winter use.

November.—If temperate and open, a little sowing may be continued in sheltered borders; but frost usually sets in early in the month, and puts a stop to cropping operations.

December.—During the latter end of November, and the open period of this month, the chief operations are digging, manuring, or trenching vacant ground, and attending to the preparation of composts. In frost, the labour exerted on the plants need only be protective; and the gardener usually occupies much of this period in pruning his trees, and attending to the more delicate plants in frames and sheltered borders. In mild weather, a few early peas and radishes may be sown in dry warm borders, and small salads and cucumbers in hotbeds.



Royal Water-lily (*Victoria regia*).

THE FLOWER-GARDEN.

FLOWERS have in all ages been cultivated by persons of leisure and taste, for the beauty and variety of their forms, colours, and fragrance. While generally healthful and exhilarating, from being pursued in the open air, flower-culture is justly reckoned a pure and harmless recreation, which, by leading to the tranquil contemplation of natural beauty, and diverting the mind from gross worldly occupations, has a positively moral, and therefore highly beneficial tendency. It often serves to awaken in previously listless minds a spirit of inquiry respecting the great phenomena of nature and the laws of vitality, which so vividly exemplify the wisdom, and power, and goodness of the Creator. It is therefore available as a useful auxiliary of education, as a stepping-stone to science, and as a means of elevating the moral character of a people, and their religious emotions. In ornamental art, too, all great designers have derived valuable aid from the vegetable kingdom: the lotus of Egyptian ornament, the honeysuckle and acanthus of the classic sculptors, are all *flowers* of architectural history; and in our own day, we find our most successful designers not merely copying the models of masters, but rather adopting their manner, and going back to nature as the direct source of their inspirations. Flower-gardening affords the ready means of studying vegetable forms, which, were they to be sought in the fields and woods, would necessitate a course of botanical study which few artists have the leisure or inclination to adopt. It has also the advantage of being alike open to the pursuit of high and low, the peasant and the peer, the overtoiled man of business and the industrious artisan. It may be followed with equal enjoyment by both sexes, and, as is well known, on every imaginable scale, from that of a single flower-pot or tiny front-plot, to the princely conservatory and exquisitely varied parterre.

The natural grace, simplicity, and attractive colouring of flowers have afforded endless themes to moralists and poets; and volumes have been penned to shew how many associations of feeling, simple and sublime, these beauteous subjects are calculated to excite. As our desire is to improve the feelings as well as to instruct the understanding, we hope to escape censure for pausing an instant over this agreeable view of the importance of floriculture, and would refer, for one of the most glowing eulogies on the subject, to the elegant work of Miss Sarah Stickney—the *Poetry of Life*. According to the well-expressed sentiments of this lady, few natural objects are more poetical, or more calculated to refine the taste, than flowers. 'From the majestic sunflower, towering above her sisters of the garden, and faithfully turning to welcome the god of day, to the little humble and well-known weed that is said to close its crimson eye before impending showers, there is scarcely a flower which may not from its loveliness, its perfume, its natural situation, or its classical association, be considered highly poetical.

'As the welcome messenger of spring, the snow-drop claims our first regard, and countless are the lays in which the praises of this little modest flower are sung. The contrast it presents of green and white—ever the most pleasing of contrasts to the human eye—may be one reason why mankind agree in their admiration of its simple beauties; but a far more powerful reason is the delightful association by which it is connected with the idea of returning spring. Perhaps we have thought long of the melting of the snow that impeded our noon-

day walk. But it vanishes at last; and there, beneath its white coverlet, lies the delicate snow-drop, so pure and pale, so true an emblem of hope, and trust, and confidence, that it might teach a lesson to the desponding, and shew the useless and inactive how invaluable are the stirrings of that energy that can work out its purpose in secret, and under oppression, and be ready in the fulness of time to make that purpose manifest and complete. The snow-drop teaches also another lesson: it marks out the progress of time. We cannot behold it without being reminded that another spring has come, and immediately our thoughts recur to the events which have taken place since last its fairy bells were expanded.

'It is of little consequence what flower comes next under consideration. A few specimens will serve the purpose of proving that these lovely productions of nature are, in their general associations, highly poetical. The primrose is one upon which we dwell with pleasure proportioned to our taste for rural scenery, and the estimate we have previously formed of the advantages of a peaceful and secluded life. In connection with this flower, imagination pictures a thatched cottage standing on the slope of the hill, and a little woody dell, whose green banks are spangled all over with yellow stars, while a troop of rosy children are gamboling on the same bank, gathering the flowers, as we used to gather them ourselves, before the toils and struggles of mortal conflict had worn us down to what we are now, and thus presenting to the mind the combined ideas of natural enjoyment, innocence, and rural peace—the more vivid, because we can remember the time when something like this was mingled with the cup of which we drank—the more touching, because we doubt whether, if such pure drops were still there, they would not to our taste have lost their sweetness.

'The violet, while it pleases by its modest, retiring beauty, possesses the additional charm of the most exquisite of all perfumes, which, inhaled with the pure and invigorating breezes of spring, always brings back in remembrance a lively conception of that delightful season. Thus, in the language of poetry, "the violet-scented gale" is synonymous with those accumulated and sweetly blended gratifications which we derive from odours, flowers, and balmy breezes; and, above all, from the contemplation of renovated nature once more bursting forth into life, and beauty, and perfection. The jasmine also, with its dark-green leaves and little silver stars, saluting us with its delicious scent through the open casement, and impregnating the whole atmosphere of the garden with its sweetness, has been sung and celebrated by so many poets, that our associations are with their numbers rather than with any intrinsic quality in the flower itself. Indeed, whatever may have first established the rank of flowers in the poetical world, they have become to us like notes of music, passed on from lyre to lyre; and whenever a chord is thrilled with the harmony of song, these images present themselves, neither impaired in their beauty nor exhausted of their sweetness for having been the medium of poetic feeling since the world began.

'It is impossible to expend a moment's thought upon the lily, without recurring to that memorable passage—"Consider the lilies of the field, how they grow. They toil not; neither do they spin; and yet I say unto you, that Solomon in all his glory was not arrayed like one of these." From the little common flower called heart's-ease, we turn to those well-known lines of Shakspeare where the fairy king so beautifully describes the "little western flower." And the forget-me-not has a thousand associations tender and touching, but unfortunately, like many other sweet things, rude hands have almost robbed it of its charm. Who can behold the pale narcissus, standing by the silent brook, its stately form reflected in the glassy mirror, without losing himself in that most fanciful of all poetical conceptions, in which the graceful youth is described as gazing upon his own beauty, until he becomes lost in admiration, and finally enamoured of himself; while hopeless Echo sighs herself away into a sound, for the love which, having centered in such an object, was neither to be bought by her caresses nor won by her despair? Through gardens, fields, forests, and even over rugged mountains, we might wander on in this fanciful quest after remote ideas of pleasurable sensation connected with present beauty and enjoyment; nor would our search be fruitless, so long as the bosom of the earth afforded a receptacle for the germinating seed—so long as the gentle gales of summer continued to waft them from the parent stem—or so long as the welcome sun looked forth upon the ever-blooming garden of nature.

'One instance more, and we have done. The "lady rose," as poets have designated this queen of beauty, claims the latest though not the least consideration in speaking of the poetry of flowers. In the poetic world, the first honours have been awarded to the rose, for what reason, it is not easy to define, unless from its exquisite combination of perfume, form, and colour, which has entitled this sovereign of flowers in one country to be mated with the nightingale; in another, to be chosen, with the distinction of red and white, as the badge of two honourable and royal houses. It would be difficult to trace the supremacy of the rose to its origin; but mankind have so generally agreed in paying homage to her charms, that our associations in the present day are chiefly with the poetic strains in which they are celebrated. After all the pains that have been taken to procure, transplant, and propagate the rose, there is one kind perpetually blooming around us through the summer months, without the aid or interference of man, which seems to defy his art to introduce a rival to its own unparalleled beauty—the common wild-rose. Blooming in the sterile waste, this lovely flower is seen unfolding its fair leaves where there is no beauty to reflect its own, and thus calling back the heart of the weary traveller to thoughts of peace and joy—reminding him that the wilderness of human life, though rugged and barren to the discontented beholder, has also its sweet flowers, not the less welcome for being unlooked for, nor the less lovely for being cherished by a hand unseen.' To these elegantly expressed sentiments nothing need be added by the writer of these pages.

MODES OF LAYING OUT FLOWER-GARDENS—FRONT-PLOTS—BOWERS.

Flowers are cultivated in the borders and parterres of gardens of a mixed kind along with kitchen vegetables and fruits; and this may be said to be the general plan in those grounds of limited space belonging to persons of moderate means. Many, however, cultivate flowers in 'flower-gardens' exclusively appropriated to them, and also in isolated clumps for the decoration of lawns. The method of culture is the same in all cases, and therefore it is unnecessary to enter into particulars with reference to the various sizes and kinds of gardens in which flowers may be grown.

The directions given in the previous sheet on the laying out, shelter, and exposure of kitchen-gardens, apply also to flower-gardens. The soil should be rich and dry, the exposure full and uninterrupted towards the sun, so that a free air may play over the ground; and means should be at hand for procuring a plentiful supply of pure soft water for irrigation.

If the garden is seen from a parlour-window, as is often the case, the plan most agreeable is to lay out the foreground as a patch of well-shaven green, which is fresh both winter and summer; on its further side there may be a semicircular border; then a walk; and next parterres of such form and size as will suit the extent of the ground. If the garden contain kitchen vegetables, they should be out of sight of the windows of the

dwelling-house, or at least not brought ostentatiously forward. 'It is more difficult,' says the author of the *Florist's Manual*, 'than may at first appear, to plan, even upon a small scale, such a piece of ground; nor, perhaps, would any but an experienced scientific eye be aware of the difficulties to be encountered in the disposal of a few shaped borders interspersed with turf. The nicety consists in arranging the different parts so as to form a connected glow of colour; to effect which, it will be necessary to place the borders in such a manner that, when viewed from the windows of the house, or from the principal entrance into the garden, one border shall not intercept the beauties of another; nor, in avoiding that error, produce one still greater—that of vacancies betwixt the borders—forming small avenues, by which the whole is separated into broken parts, and the general effect lost. Another point to be attended to is, the just proportion of green turf, which, without nice observation, will be too much or too little for the colour with which it is blended; and, lastly, the breadth of the flower-borders should not be greater than what will place the plants within reach of the gardener's arm without the necessity of treading upon the soil, the mark of footsteps being a deformity wherever it appears among flowers.'

Whether all the flowers of a kind—such, for instance, as violets, hyacinths, &c.—should be cultivated together in beds, or interspersed and mingled with others, is a matter for taste to decide. Dr Neill judiciously observed, on the choice of flowers for borders: 'The plants are arranged in mingled flower-borders, partly according to their size, and partly according to their colour. The tallest are planted in the back part, those of middling size occupy the centre, and those of humble growth are placed in front. The beauty of a flower-border, when in bloom, depends very much on the tasteful disposition of the plants in regard to colour. By intermingling plants which grow in succession, the beauty of the border may be prolonged. In a botanic garden, the same plant cannot be repeated in the same border; but in the common flower-garden, a plant, if deemed ornamental, may be often repeated with the best effect; nothing can be finer, for example, than to see many plants of double scarlet lychnis, double sweet-william, or double purple jacobæa.' The practice of growing flowers in beds of one kind has of late years, however, become very prevalent, and has this advantage, that it gives bolder masses of colour, and enables the florist to cultivate in the open ground, and with the best effect, many tender plants that would be lost in a mixed border.

The Dutch, who are among the best flower-gardeners in the world, have lately begun to copy the English in ornamenting turf-lawns with plots of various kinds of flowers; but in all their large and regular gardens, they still dispose each kind of flowers by themselves. 'We ridicule this plan,' says Hogg, in his *Treatise on Flowers*, 'because it exhibits too great a sameness and formality; like a nosegay that is composed of one sort of flowers only, however sweet and beautiful they may be, they lose the power to please, because they want variety. It must undoubtedly be acknowledged, that a parterre, no matter in what form—whether circular or square, elliptical or oblong—where all the shrubs, plants, and flowers in it, like the flowers in a tastefully arranged bouquet, are variously disposed in neat and regulated order, is a delightful spectacle, and worthy of general imitation. Yet still, in some particular cases, I am disposed to copy the Dutchman; and I would have my bed of hyacinths distinct, my anemones, my ranunculuses, my pinks, my carnations distinct, and even my beds of hollyhocks, double blue violets, and dwarf larkspurs distinct, to say nothing of different sorts of roses. Independently of the less trouble you have in cultivating them when kept separate, you have beauty in masses, and you have likewise their fragrance and perfume so concentrated, that they are not lost in air, but powerfully inhaled when you approach them.'

As to front-plots in towns and suburbs, if they be limited to a few square yards, it will be better not to attempt the growth of flowers at all, but to lay them down in greensward, if it will grow, or clean gravel, with perhaps a variegated holly, box-tree, laurel, flowering currant, sweet-brier, rose, or some other hardy shrub, to enliven them. Nothing, however, can be more wretched than a few sickly plants struggling for a miserable existence amid the dust and smoke of a town; and a person of good taste will never attempt the growth of flowers unless he can command the requisite amount of air and sunshine. In laying out little front-plots of this description, circular, oval, oblong, and other simple forms should be preferred; for nothing looks more ridiculous than the imitation of labyrinths and intricate designs on so small a scale. A few plain forms, in keeping with the front of the building and size of the plot, may produce elegance; but intricate divisions, with lines of gravel between, scarcely broad enough for a human foot, are toyish and trifling in the extreme. A neat box-edging should always be preferred.

An error not uncommon in deciding what flowers shall be planted, is to select numbers merely for their rarity or novelty, without reference to what will be their appearance when in bloom; a plan that generally leads to disappointment. Unless for botanical illustration, make a choice of flowers on two principles—those which will be beautiful when in bloom, although common; and those which will bloom at the particular seasons required, to insure a succession of variegated beauty from spring to autumn.

Bowers and rustic seats often form a pleasant feature in connection with the flower-garden. The forms of these are so numerous, that there is ample scope for choice; but there is one mode of forming a bower so novel and natural in character, that it is deserving of special notice. 'It sometimes happens,' says a correspondent of the *Garden Companion*, 'when trees are cut down to a few inches from the ground, that they send up shoots all round the stump. These shoots grow to a greater or less height, according to circumstances, and are frequently a source of annoyance.' One mode of overcoming this evil, or rather of converting an object of annoyance into an object of utility and ornament, is illustrated by the accompanying sketches. Fig. 1 shews

Fig. 1.—Tree-stump preparing for a Bower.

the stump of a tree (ash), with the young branches grown up round it; and fig. 2 illustrates the fashion in which these branches may be made to form an elegant canopy to one of the most natural of rustic seats—the stump of the tree—which may, however, be provided with a soft cushion if required. The branches need simply be tied together by means of wire; and if a few plants of ivy and brier, with one or two of the more choice climbing-roses, are planted around the base,

the whole will soon become very compact and beautiful. The wires should not be tied tightly, lest they cut the

Fig. 2.—The same, more advanced.

branches in the course of time; and perhaps, for this reason, ordinary string-ties would be preferable.

CHARACTER AND TREATMENT OF FLOWERS.

The design of the flower-gardener is less to produce size and strength in his plants, than to cause them effectually to bloom: he wishes a fine corolla. It is proper, then, to mention, that whatever tends to give excessive vigour to the stems, will prevent the formation of flower-buds. Thus a too rich and moist soil, or recent manure, is injurious.

Flowering-plants are usually divided into the following kinds: *Annuals*—plants which require to be sown annually, as they live and bloom only one season. *Biennials*, which do not blossom till the second season after sowing, remain a certain time in perfection, and then die. They are produced by seed, but some of the finest double varieties are continued by cuttings. *Perennials* are plants which continue for many seasons to grow and blossom annually. The greater number of our fine flowers and fruits are exotics—plants of foreign origin, which have been introduced into this country. Many are suited to our climate, but others require to exist in greenhouses and hothouses, or under glass frames, for at least a part of the year, and to these the term exotic more specially applies. Asiatic plants are remarkable for their superior beauty; African plants for their thick and succulent leaves, as in the case of the *Cacti;* and the American plants for the length and smoothness of their leaves, and for a singularity in the shape of the flower and fruit. The flowers of European plants are but rarely showy. Plants indigenous to polar and mountainous regions are generally low, with small compressed leaves, but with flowers large in proportion. Plants indigenous to New Holland (or Australia) are distinguishable for small and dry leaves, that have often a shrivelled appearance. In Arabia, they are low and dwarfish; in the Archipelago, they are generally shrubby, and furnished with prickles; while in the Canary Islands, many plants, which in other countries are merely herbs, assume the stature of shrubs and trees.

The different kinds of plants generally cultivated for their blossoms are either *herbaceous*—having annual stems; or *shrubby*—having permanent ligneous or woody stems. A *deciduous* tree or shrub is one which sheds its leaves every winter, and reproduces them in spring. An *evergreen* is a shrub which retains its leaves during winter, but casts them in spring as the new buds come out.

The prevailing colours of flowers are yellow, orange, white, pink, scarlet, red, blue, purple; and many are variegated, or composed of different tints. Proper culture, with pure air and sunshine, increase the brilliancy of the tints, and give massiveness to the corollas. Plants of kindred species may likewise be improved by hybridising or crossing, the general principle of which is the artificial application of the pollen of one plant to another (see VEGETABLE PHYSIOLOGY, pp. 74–5 and 80). By this means, some of the most beautiful flowers have been originated. Soil and climate, however, are the great means of improvement. The changes effected on the daisy, the rose, and the violet, will here occur to remembrance, as striking instances of metamorphoses induced by culture and change of habitat. Speaking of the laws by which a change of colour is produced, Dr Lindley observes: 'A blue flower will change to white or red, but not to bright-yellow; a bright-yellow flower will become white or red, but never blue. Thus the hyacinth, of which the primitive colour is blue, produces abundance of white and red varieties, but nothing that can be compared to bright-yellow; the yellow hyacinths, as they are called, being a sort of pale yellow-ochre colour, verging to green. Again, the ranunculus, which is originally of an intense yellow, sports into scarlet, red, purple, and almost any colour but blue. White flowers, which have a tendency to produce red, will never sport to blue, although they will to yellow—the rose, for example, and the chrysanthemum. It is also probable that white flowers, with a tendency to produce blue, will not vary to yellow; but of this I have no instance at hand.'

Propagation.

Dividing the Root.—This is one of the most simple methods of propagation. The root of the growing plant is partially uncovered, and one or more portions are removed; the root is then covered up, and the detached parts transplanted in soft earth prepared to receive them. Nine-tenths of herbaceous perennials may be treated in this way.

Suckers.—These are young shoots thrown up from the roots of the main plant, round which they cluster. They may be removed by taking up along with them a part of the root, as in the preceding method. They should be removed in spring, after the plant has begun growing, and immediately planted out. If any flower-buds be developed on them, take them off, so as to give strength to the leaf and root-developing powers to the plant.

Layers.—Some plants send out layers or runners along the ground; these have joints at certain points, which have a tendency to take root, and become the centre of a new plant. Thus a running plant will speedily cover, as with a net-work, a large space of ground. Nothing is more easy than to propagate by causing the layers of some plants to take root. In the case of the carnation and pink, the young side-shoots called *grass* are selected for layering. The shoots are stripped of their lower leaves, and the stem is cut half through by an oblique slit near the base; it is then fixed to the ground, with a hooked stick or peg, and is covered slightly with mould, giving a little moisture. Roots will in general strike out in a few weeks; and at the end of the season, the plant is ready for being cut from its parent and transplanted.

Pipings.—Propagation by piping is an expeditious mode of raising young plants. 'Take off the upper and young part of each shoot close below a joint, with a sharp knife, cutting each off at the third joint, or little knob; and then cut the top leaves down pretty short, and take off the lower and discoloured ones. When you plant the pipings, let the earth be light and sandy, and recently loosened; dibble no hole, but gently thrust each piping half-way down into the soft earth, and fix it in the bed. Water them often, if the weather is dry, but moderately, just to keep them moist; and shade them from the hot sun in the day. If pipings are

covered with a hand-glass, they root sooner than those which are exposed. Piping is done in June and July; and the plants will be well rooted and fit to plant out in October.'

Cuttings are strong shoots cut from the parent stem or branch, and set in the ground. The cutting should be cut off slantingly and smoothly; and the soil requires to be dry, or not too moist. Roses and honeysuckles are among the shrubby plants usually propagated by cuttings; and familiar examples of more succulent ones are seen in geraniums, verbenas, petunias, fuchsias, calceolarias, &c.

Budding is a method of propagation chiefly used in connection with fruit-trees; but as it is likewise applicable to rose-bushes, it may here be described. It is a species of grafting, and consists in inserting the fresh-cut bud beneath the bark of another plant. A leaf-bud, easily known by its tapering point, should be alone selected, and not a bud in which a flower is developed. The leaf on the selected bud is to be taken off, for if it remained, it would exhaust the sap, and the bud would in all likelihood wither and die. Along with the bud, a small slip of bark is to be taken; and if this bark separate freely, it is a test of there being sap enough to form a union. The slip of bark is to be inserted beneath the bark of the other plant, in a slit made for the purpose, and the whole tied with a strip of mat or gutta-percha, to keep out the air. The subjoined cut

Fig. 3.

represents the various parts in budding: *a* is the bud cut out, with a shield of bark attached to it; *b*, the stem, with a slit in the bark to receive the shield attached to the bud; *c*, the bud inserted, and the leaf cut away.

SELECT FLOWERS FOR THE GARDEN.

Flowering plants are now so numerous, both as respects species and varieties, that a bare list of them would more than fill the present sheet. All, therefore, that can be reasonably expected from us is a few hints as to those which are most approved, and cultivated chiefly in the open air. A person with little experience should stock his garden only by degrees—adding a small number of different sorts every year, according to fancy, and what he finds to be the capabilities of the soil and exposure. In commencing to make a choice for a moderately sized garden, or for still smaller plots of ground and borders, we should also recommend the plan of cultivating a mixed variety of different colours and different heights—those which are smallest being in front, and nearest the eye, and the other rows rising in height and massiveness as they recede. With as few as four colours, four sizes, and six different periods of coming into bloom, a mingled border may be established with ninety-six sorts, which will present a pleasing assemblage to the eye.

Annuals.

Some annuals are called *hardy*, and others *half-hardy*. The hardy kinds will grow and blossom in open borders, without artificial heat or protection; those which are more tender will also grow in the open air, but are improved by being brought forward under hand-glasses. Of the delicate class of annuals which must be constantly kept under glass frames, it is not our purpose to speak. The greater number of annuals may be sown in the month of April. The soil should be fine, and have a warm exposure; and on being sown, cover the seeds only slightly with mould; peas and lupines should be an inch below the surface. If the weather be dry, irrigate with pure soft water occasionally.

Among the vast number of annuals that offer themselves to the choice of the gardener, the following, most having varieties as to colour, may be mentioned as taking the lead in the *half-hardy kinds:* African marigold, French marigold, China aster, marvel of Peru, sweet sultan, Indian pink, convolvulus, amaranthus, ten-week stock, &c. *Hardy kinds:* Adonis, candytuft, larkspur, lupines, sunflower, lavatera, poppy, nasturtium, sweet pea, Venus's looking-glass, Virginian stock, mignonette, purple jacobæa, Clarkias, Collinsias, Nemophila insignis, maculata, and many others.

If annuals are required on a more extended scale, the best plan is to leave the selection to a respectable nurseryman. Such a person will at least present a copious list to make your choice from, and mention the size or height to which the plants will respectively grow.

Whether tender or hardy, all annuals should be carefully trimmed, and kept from straggling. Some will require thinning. Preserve the strongest blossoms for seed; and remove withered and imperfect blooms, to add vigour to those which remain.

Biennials.

The difference between biennials and perennials is in many instances very ill defined. A biennial is said to be a plant which, when sown, does not bloom till the following summer, and dies out in the course of autumn. This is true as respects some biennials, but it is equally certain that many will survive and bloom year after year, the same as perennials. For instance, carnations are called biennials, although it is notorious that these plants will grow and multiply by roots in the same spot, year after year, with only ordinary culture.

Among biennial plants suitable for ordinary flower-gardens are included the following, each having several varieties: Canterbury bells, carnation, pink, hollyhock, sweet-william, wallflower, Lavatera arborea, purple digitalis, and stock gilliflower. Some of these are very beautiful, and none more so than carnations.

The *Carnation.*—There are many varieties of the carnation, but all are arranged in three classes—flakes, bizarres, and picotees. Flake carnations possess but two colours, with large stripes through the petals. Bizarres have three shades of colour, also in stripes. Picotees have a white or yellow ground, marked on the margins with purple or some other colour. Carnations should have a flower at least three inches in diameter, with the edges of the petals waving or smooth, not serrated. The petals must fill the calyx, but not to bursting; if a calyx burst, the flower has been imperfectly cultivated. 'The calyx,' says Hogg, 'should be at least one inch in length, terminating with broad points sufficiently strong to hold the narrow bases of the petals in a close and circular body. Whatever colours the flowers may be possessed of, they should be perfectly distinct, and disposed in long regular stripes, broadest at the edge of the lamina, and gradually becoming narrower as they approach the claw of the petal. Each petal should have a due proportion of white, one-half, or nearly so, which should be perfectly clear, and free from spots. Bizarres, or such as contain two colours upon a white ground, are esteemed rather preferable to flakes, which have but one, especially when their colours are remarkably rich and very regularly distributed. Scarlet, purple, and pink, are the three colours which predominate in the carnation. When the pink flake is very high in colour, it is customary to distinguish it by the appellation of rose flake.'

The following, which we copy from an agreeable

horticultural treatise, *The Manse Garden*, are the plainest directions we have seen respecting the culture of carnations: 'The best soil for carnations is good loam, enriched with well-rotted stable-dung, and quickened with a little sand. The quantity of manure can only be determined by the previous strength of the ground: if made too rich, the flowers will lose their fine colours; if left too poor, they will want vigour. No recent manure should ever come near a fine plant. Let the ground be prepared before winter with dung, and a rough furrow laid up to the frost. In April, give a fresh digging, and plant in rows three feet by two. This width is to make room for layers, without which a fine blow of carnations cannot be maintained above one year. As the plants shoot up, they must be tied to neat green rods; and in order to have a fine blow, superfluous flower-buds must be pinched off, leaving only three or four to each stem. The young shoots near the ground, which do not run to flower, are denominated grass; and from these the layers are selected. The operation is somewhat nice, but when rightly done, is always successful, and good flowers are thus preserved and multiplied from year to year. Towards the end of July, stir up the ground about the plants, and mix with the soil a little old well-wrought compost. Have at hand a sharp penknife, a trowel, and a number of small pegs with an angle at the head: pieces of fern will do, or wood of no more strength than to bear pushing into the ground. Scoop out the earth in the form of a basin around each plant; select the strongest grassy shoots for layers, and remove such as are in the way; crop the top leaves an inch from the heart, and pinch off all the rest, taking care not to peel the stem. Begin an incision on the under side of the shoot, a little below the second joint from the top, and cut upwards till the joint is slit in the middle. Set the pointed extremity made by the slit into the bottom of the excavation, and there fix it with the peg; place the head of the shoot erect, fill in the earth, make it firm, and finish the work with a good watering. The young plants will be ready for removal by the end of autumn, when they may be set in flower-pots if the soil is too damp, and apt to cause rotting in winter; but if sufficiently dry, the layers may remain till spring, and it will be of use before winter to earth them up, sloping and beating the mould about them so as to throw off the rain. Although the propagation of this plant by pipings—as the grass-shoots taken off and stuck in the ground are called—is by no means so sure as the above method, yet of a number some will take root; and as pipings are more easily procured than plants, the experiment may be made. If carried to some distance, steep the slips in water till they swell to their proper size; trim them as above directed, and set them firm into prepared soil; water plentifully, and set over them a hand-glass, first throwing water on the glass, and then earth to darken it, and let it not be stirred for some days, it being found that a deficiency both of light and air promotes the striking of slips—probably on this principle, that the sick, having no appetite, must avoid the exertion which requires food as well as that which food requires.' When fully grown, the flower-stems should be tied with a strip of bast to a small stake or green wire thrust into the ground at their side.

The *Hollyhock* is a splendid flowering plant, and exceeds all others in stature. With good soil, shelter, and proper exposure, it will attain a height of twelve or fourteen feet, and generally reaches seven or eight. It is a substantial herbaceous plant, with a thick stem, along which, to the top, are the broad showy blossoms; and from this attractive appearance it is very suitable to ornament fronts of cottages, edgings to shrubberies, or the centre of clumps in lawns. The colours are very various; as pink, dark purple, yellow, &c.—the double sorts being the richest and most esteemed. The seeds of hollyhocks are sown in May; and in September or October the young plants are transplanted into the ground where they are intended to blossom; but the improved varieties of this flower that have been brought into existence within the last few years, require to be propagated by cuttings alone. Although classed as biennials, the plants will spring and bloom for a number of years.

Wallflower.—There are several sorts of this fragrant plant, those flowers which are dark and most massive being most highly esteemed. Their perfume is very pleasing, and their culture no way troublesome. 'To insure a succession of the best breed—and the method applies to the double flowering, which yields no seed, and cannot otherwise be preserved—about the beginning of July pinch off slips or young shoots of five or six inches in length, taken only from the finest stocks; crop the leaves, and strip the rest of the stem bare; dibble the slips so prepared into a bed newly dug, and shaded by trees or a north wall. Sprinkle them with water, and shade any part to which the sun has access. Not one will go back; and in this way a profusion of one of the sweetest flowers, and the best of its kind, may be had from year to year.'

Perennials—Bulbs.

Under this head may be included the hyacinth, narcissus, iris, lily, tulip, snow-drop, crocus, and others.

The *Hyacinth* has a tapering bulb, shoots up long green leaves, and in the centre is a stalk on which the blooms, in the form of bells, grow all round, causing it to droop or bend. There are numerous varieties, differing in colour—as blue, red, and white. The hyacinth is a favourite of the Dutch, by whom it has, like the tulip, been brought to great perfection. A sandy soil and saline atmosphere, with a warm exposure, are favourable in developing its properties. In the British Islands, the hyacinth will endure the winter in the ground, and is among the earliest blossoming plants of spring. In Holland, the bulbs are lifted and carefully stored during winter. The grower who desires to meet with success, must obtain an annual supply of Dutch bulbs, which are to be had from the seedsmen. The domestic culture of this flower will be alluded to under another head.

Of the *Narcissus* there are many varieties, which include daffodils, white narcissus, jonquils, and polyanthus narcissus. Most have a lightish-yellow flower, with a deeper yellow cup. A fine narcissus has tall and firm leaves, and from the centre springs the round tube-like flower-stalk, on the top of which is the bright-yellow bloom, with petals spreading out like the rays of a star: the criterion of excellence is massiveness and distinctness of colour in the corolla. Of the polyanthus species there are at least a hundred sorts, sulphur-coloured, single and double, white, &c. Like hyacinths, the bulbs may remain in the ground during winter.

Of the *Iris* there are various sorts, all of them beautiful from the delicacy of colour. The Persian iris is low, with delicate blue and violet blossoms; the Chalcedonian is taller, and distinguished by the great size and magnificence of its flower, which is a purple-blue striped with white; the English is of still greater height, and has flowers of large size. None require much sun.

The *Lily* is a plant equally tall with the larger iris. There are many species, with different colours—white, orange, and carmine. The orange, speckled with dark dots, is the more common. This plant will grow and bloom with little sun, or under the shade of trees. The effect of the orange-coloured blossom is pleasing among green plants which require to be set off by a contrast. The Japan lilies, not long since introduced to flower-gardening, are found to be most valuable ornamental plants, whether they be treated as exotics, or as hardy herbaceous plants. *Lilium giganteum* is also a striking addition to our lists, from India.

The *Tulip* is the pride of the garden, or at least stands pre-eminent in general estimation. Like many other bulbs, it is a native of the Levant, and was brought to its perfection in Holland, where tulip-fancying was at one period a mania, and the bulb is still a large article of trade. The finest tulip-gardens are at Haarlem, which has a warm and saline climate, with a soil light and rich. Round the roots and over the beds, sand is freely scattered, so that the tulips seem as if growing from a sandy beach. In planting in this country, follow the same practice. Plant in October, or early in November. In forming a bed of tulips, the bulbs should be set at a distance of seven inches apart, and in straight rows, taking care to mix the different colours. To raise from seed, or to improve the varieties by crossing, is a work of time, and not to be thought of in ordinary circumstances. The following is Hogg's criterion of a fine variegated late tulip: 'The stem should be strong, elastic, and erect, and about thirty inches above the surface of the bed. The flower should be large, and composed of six petals: these should proceed a little horizontally at first, and then turn upwards, forming almost a perfect cup with a round bottom, rather widest at the top. The three exterior petals should be rather larger than the three interior ones, and broader at their base: all the petals should have perfectly entire edges, free from notch or serrature; the top of each should be broad and well rounded; the ground colour of the flower, at the bottom of the cup, should be clear white or yellow; and the various rich-coloured stripes, which are the principal ornament of a fine tulip, should be regular, bold, and distinct on the margin, and terminate in fine broken points, elegantly feathered or pencilled. The centre of each leaf or petal should contain one or more bold blotches or stripes, intermixed with small portions of the original or breeder colour, abruptly broken into many irregular obtuse points. Some florists are of opinion that the central stripes or blotches do not contribute to the beauty and elegance of the tulip, unless confined to a narrow stripe exactly down the centre, and that they should be perfectly free from any remains of the original or breeder colour. It is certain that such appear very beautiful and delicate, especially when they have a regular narrow feathering at the edge; but the greatest connoisseurs in this flower unanimously agree that it denotes superior merit when the tulip abounds with rich colouring, distributed in a distinct and regular manner throughout the flower, except in the bottom of the cup, which should be a clear bright white or yellow, free from stain or tinge, in order to constitute a perfect flower.'

In order to have tulips in anything like perfection, they require great care. As strong sunshine injures them, they must be covered with a slight awning from the sun's rays. They must also on no account be allowed to go to seed, for in that case the bulb is exhausted; to prevent which, they should be watched when they approach perfection, and the head and stalk cut off. A usual signal for cutting is when they cease closing at sunset, or when the edges of the petals exhibit the slightest appearance of withering. They should be cut rather too early than too late. After cutting, admit the sun to the stems; and when these wither, which may be in June or July, lift the bulbs, and lay them aside in a dry airy situation; there let them remain till the period for planting, which is the end of October or beginning of November.

The *Crocus* and the *Snow-drop* are two small bulbous plants, so well known for their hardy growth, that little need be said of them. Crocuses are very various in colour—blue, yellow, white, and so forth; and the principal thing in planting is to dispose these colours in a pleasing variety. Crocuses, like other bulbs, require occasional transplanting: this may be done in October. Of the snow-drop, there is a double-flowered variety; and another species (*Galanthus plicatus*), the Crimean snow-drop, was brought into notice during the Russian war.

Perennials—Tubers.

In this group, the *Dahlia* (named from Dahl, a Swedish botanist), both from its beauty and size, deserves the first place. It is a native of the temperate plains of South America, and requires a dry and airy situation for its growth. The tubers at the root resemble long potatoes, and as they spread to some distance, the plant should have a free space of from two to three feet all round. The stems, at and near the top of which are the rose-like blossoms, rise to a height of four feet or more, and require to be supported by stakes. A new plant may be procured by separating a part of the root, to which a stem is attached. Frost at once blights the green stalks; and when these seem utterly withered and dried, carefully lift the tubers, and place them in a dry situation for the winter. In April, or early in May, they must be sprung on old manure under a glass frame, and then planted out, and occasionally watered. Dahlias are now found of almost every shade of colour, except blue, every year adding its novelty.

The *Ranunculus* is a stock beauty in all gardens, and it has some hundreds of varieties. The tubers are small. The blossom resembles a compact small rose of a flattish form. The soil in which the plants are placed requires to be fine and in good heart. In planting ranunculuses and dahlias, the colours should be arranged so as to produce an agreeable variety.

Fibrous-rooted Perennials.

The genera, species, and varieties of flowering plants with fibrous roots include the greater part of vegetable productions. A few of those most prized are all we need notice. Let us take first the humble *Daisy* (day's-eye), which has been cultivated from the wild *gowan* or daisy, the 'wee, modest, crimson-tipped flower,' and is now found in many varieties—the mottled crimson and white, and the pure crimson, being the more common. This plant is the hardiest of the herbaceous tribe, keeps longest in bloom of any, and may be propagated to any extent by simple separation of the roots.

Dielytra.—The Chinese Dielytra (*D. spectabilis*) is suited either to the greenhouse or open air, and is one of our best novelties. Several allied plants, including the Fumitories, are also well worthy of cultivation in the borders.

The *Primrose* family includes several pretty flowering plants. There is no great beauty in the primrose as a garden-plant, but it is useful as an early spring-flower, and succeeds the crocus in giving colour to the borders. The highest cultivated of the race is the *Polyanthus*, which sends up stems loaded at top with a bunch of flowers. The colour most admired is that shaded with a light and dark rich crimson, resembling velvet, relieved by a bright golden hue. The *Auricula* (*Primula Auricula*) is a larger plant, but varying in colour, and more delicate in many respects. It flourishes best in rich soil from old turf and rotted cow-dung. The chief colours are red, pink, crimson, purple, apple-green, and mulberry. On the petals there is a fine meal, which is injured and marked by drops of rain or artificial irrigation; and therefore flower-fanciers take care to shelter the plants with frames, and allow no drops from the watering-pot to touch them. When treated with attention, a bed of auriculas may be rendered very beautiful.

The *Campanula*, or pyramidal bell-flower, in its different varieties, blue and white, is a graceful flower, with pendent bells, which should be found in all tastefully laid out borders. It may be kept long in flower, by cutting off the blooms as soon as they begin to wither. The large herbaceous *Peony*, with its brilliant and deep crimson flower, is another choice plant; it requires little care.

Pansy.—By the French, the cultivated violet or heart's-

ease is called *pensée* (thought); hence our name pansy. No flower in the garden has lately engaged so much attention as the heart's-ease; and by means of culture and hybridising, it has attained great perfection as respects size and richness of colour. 'The most approved method of propagation is by taking off young slips in the autumn, which is the best time, as then the ground and weather are most suitable for the formation of rootlets, on account of its dampness and dulness; [but the season for striking cuttings will depend upon the time when they are wanted to flower]. A bed is prepared of light but rich soil, raised a little above the path, in order to drain off all superfluous moisture. The cuttings are then made ready, by stripping them of their under leaves, and cutting close below the bottom joint, from which the roots must spring; for if this is not done, the cutting will decay to that joint, which frequently destroys the whole. After the bed is prepared, the cuttings are arranged according to their varieties, each sort being marked by a tally-stick, numbered or named according to the pleasure of the owner. The cuttings will be found to be well rooted in about six weeks, when they may be planted out for blooming in the spring, or potted to keep over winter in a frame. The soil in which the pansy is found to flourish best is a compost of cow-dung one-half, fresh loam one-quarter part, leaf-mould one-eighth part, and coarse sand one-eighth; but peat-soil should on no account be intermixed, as it burns up the pansy completely. These ingredients should be well mingled together, and purified from worms and slugs by having lime-water frequently thrown over the heap, and in a short time it will be fit for use. The situation best adapted for the heart's-ease is one which is sheltered from the mid-day sun, but which receives a little in the morning, as it is then not so powerful as to injure the colours. Transplanting may be performed at any season, but in doing so an error is prevalent. We see the plants taken up with a ball of earth around them, and planted again with it. Now, as everything deteriorates the soil in which it grows, and as the pansy entirely pierces every particle of earth its roots can reach, therefore that which we take up with it must be entirely exhausted. When replanted, the pansy can receive very little food from its new situation, as its roots do not by nature straggle far from the stem. To prevent this starvation, it would be much better to wash away all the soil from the roots, and replant the flower with its roots unconfined; then it would be able to seek food for itself abundantly, and thereby produce much larger blossoms.'

To the amateur, the selection of suitable varieties of florists' flowers is often a matter of great consideration, and in the case of pansies, it is especially difficult; for those kinds which gain the principal prizes at flower-shows are frequently ill adapted for the usual purposes of ornament, being often shy bloomers, or defective in not shewing their flowers well above the foliage. We have therefore requested Mr Tait, a grower of the pansy who has had great experience, to give us the results of his observation, which he does in the following lists:

Varieties best adapted for general ornament in the flower-garden, being free bloomers and of good habit, shewing their flowers well above the foliage: CLASS I. *Selfs* (flowers of one colour only)—Blanche, Countess of Strathmore, Duke of Perth, Flower of the Day, Yellow Climax, Lord Dunfermline. CLASS II. *Yellow-grounds*, with margins of blue, purple, crimson, or maroon — Commander-in-chief, Cyrus, Lady Emily, Lord Raglan, Lustre, Sir J. Cathcart. CLASS III. *White or light grounds*, with margins of blue, purple, lilac, or mulberry—British Queen, Colonel Windham, Constancy, Miss Talbot, Princess.

Varieties adapted for competition: CLASS I. Jeanie, Mesmerist, Royal Albert, Sovereign. CLASS II. Admiral Napier, Alice, Duke of Norfolk, Emperor, Father Gavazzi, Monarch, Rubens. CLASS III. Countess of Rosslyn, Eugénie, Earl of Mansfield, Miriam, Nonpareil, Royal Standard, Sir Colin Campbell.

Mr Tait states, that in planting *beds* for show, he takes British Queen for white ground, with light rosy-purple margin; Miss Talbot for white ground, with dark-purple margin; Sir J. Cathcart for yellow ground, with bright reddish-crimson margin; and Lustre for yellow ground, with very dark margin. Duke of Perth is perhaps the best dark self for making a bed; Yellow Climax, the best yellow self for a bed; and Blanche the best (indeed the only really good white) self for a bed. Some of the fancy varieties are well adapted for bedding purposes.

Shrubs—Evergreens—Climbers, &c.

Among these, the *Rose* unquestionably deserves the first place, having from time immemorial been a favourite in every garden. There are some hundreds of species and varieties of roses; among which are included China-roses, hardy climbing-roses, moss-roses, Scotch roses, &c. The China-rose is delicate, with few petals in the flower, and yields a succession of blossoms through a great part of the year; it is hardy, and is green and flourishing in winter. Among red roses, the moss-rose is the most beautiful, and next it may rank the cabbage-rose; but both are excelled in fragrance by the leaves of the *sweet-brier*, a rose-shrub which, for the sake of the delicious odour of its hardy green leaves, should have a place in every garden. All kinds of rose-bushes are exhaustive of the soil, and should be frequently manured, if not transplanted to fresh mould. In order to keep them in bloom, cut off all blossoms which seem about to wither. The branches require careful pruning. For adorning the walls of summer-houses, cottages, &c., the *Honeysuckle* excels, and should, both for its beauty and fragrance, by all means have a place in every garden, however humble. The honeysuckle is a *twining* plant, and has a tendency to climb in a spiral direction from right to left, which requires to be accommodated. The *Hop* is sometimes grown in gardens, and allowed to climb on tall poles. In point of massiveness of green surface, the honeysuckle is surpassed by the *jasmine*, a tall running shrub, growing up in numerous branches, which, being well covered with small narrow leaves, is very suitable for leading up to verandahs or concealing pieces of wall. It does not adhere, and requires nailing; when carefully treated, its massive green and elegantly drooping small branches have a pleasing effect. *Ivy*, the most pertinacious of climbing-plants, will grow almost anywhere, and only requires pruning every winter or spring to keep it within bounds.

Among the various tall bushy shrubs most appropriate as an ornamental background in gardens, are the different species of azaleas, laurustine, rhododendrons, and lilacs. The *Laurustine* yields a plenteous and early supply of small variegated blossoms. The *Arbutus* is likewise a beautiful shrub, but more suitable as an embellishment in lawns; it has small greenish bell-shaped flowers, and yields a strawberry-like fruit in warm exposures. Perhaps all out-of-door exotic shrubs should yield the palm of beauty to the *Ribes sanguineum*, a plant profusely adorned with small red blossoms, which appear in spring. It resembles the common currant.

Evergreens constitute a class of shrubby plants, more suitable for the ornamental front-plots of dwelling-houses, or for approaches and lawns, than for ordinary flower-gardens; because, although the green of the leaves is pleasing in winter, when other vegetation is dead, these plants are very exhaustive of the soil; often prevent the sun from getting to the borders; and keep the ground in a litter with fallen leaves at a time when trimness is expected. Many species of evergreens are now cultivated in gentlemen's grounds; but those which

are most generally esteemed for ornamental plots or other limited situations, are the various tribes of *Laurels*, *Alaternus*, *Arborvitæ*, *Holly*, *Juniper*, and *Box*. With proper care, any of these may be lifted and transplanted into situations more agreeable to the eye, either at the beginning of September or May, when young shoots are preparing to burst forth. The plan is to dig all round them, at a distance equal to the compass of the branches, sinking the trench to a point beneath the sole of the plant; then lift them bodily with the whole mass or ball of earth round the roots. A pit must be prepared for the reception of the ball, and when placed in its new situation, fill in the rest of the pit with fine earth, laying the rootlets straight, and packing in all neatly to the surface. A copious stream of water must now be poured from a watering-pot upon the newly placed mould, round the stem; this carries the particles of earth to the rootlets, surrounding each with its proper nourishment, and giving solidity to the whole. If likely to be exposed to winds, the plant should be supported till thoroughly rooted in its new abode. (See ARBORICULTURE.)

Succession of Bloom.

The directions given in the foregoing pages, and in the floricultural calendar appended, it is hoped, will assist in leading to an arrangement whereby a constant succession of blossom may be obtained, for on this much depends. As a further aid, we offer the following hints, furnished by a correspondent to the *Gardeners' Chronicle:* 'It is the desire of every one who possesses a garden, to have as much variety of colour and succession of gaiety throughout the season as the situation and means of the possessor can accomplish; yet in viewing most gardens, even where expense is not an object, borders devoted to the cultivation of particular plants may frequently be observed to be attractive only when such plants are in blossom, and looking bare, if not unsightly, after the bloom is over. Supposing equal skill in the cultivation of plants in general to exist among gardeners, the great superiority in effect of one garden beyond another, consists in the distribution and arrangement of the plants themselves, so that a succession of blossom, and a due contrast of colour should, where practicable, keep every border furnished even to the end of autumn. In this respect, most gardens are deficient. Succession is not attended to, except for the more limited space and favoured spots near the mansion, or in front of the conservatory. In most gardens, it is considered sufficient to keep any border where plants have blossomed free from weeds and neatly raked. To the mind of the gardener, this border tells its own history, of the beauty of which he had boasted but a few weeks since; but the visitor or casual observer who walks through the garden, only seeking to please his eye with varied gaiety, makes no allowance for the past which he has not seen; and remarks, that though some parts are beautiful, a great portion of the ground has nothing worth looking at.

'By the subjoined method, the comparative gaiety of the scene may be kept up, and a relief to the eye, not without interest to the observer, preserved. Mix the seeds of the following well-known annuals:

Mignonette,	Heart's-case,
Carnation poppy,	Clarkia pulchella,
Papaver amœnum,	" alba.
Dwarf Dutch poppy,	Godetia of all sorts,
French poppy,	Antirrhinum majus,
Branching larkspur,	" sparteum,
Eschocholtzia Californica,	" versicolor.
" crocea,	Collinsia bicolor,
Campanula speculum,	Coreopsis tinctoria,
Candytuft, varieties,	Convolvulus minor,
Nasturtium,	Gilia tricolor, and other species.
Centaurea Cyanus, various.	

Then let this mixture of seed be very thinly scattered upon the borders early in the spring; it need not interfere with any ordinary work on the borders that may be required afterwards, and in places where the ground may be disturbed, many of the seeds will only appear at a subsequent period, and consequently flower later in the autumn. Most of these annuals will continue flowering until the frost kills them, and if not removed too soon, will leave behind them sufficient seed for years to come. Every gardener has remarked the strength, the beauty, and the effect of single plants of self-sown annuals that spring up occasionally in a flower-border, and have escaped that destruction which the merciless hoe, in the hand of the undiscriminating labourer, inevitably entails upon them; yet, if the intelligent labourer is properly instructed, he will soon learn to confine his extermination to weeds, and his skilful eye will spare the annuals at proper intervals.

'One case yet remains of much consequence to present as well as to future effect, though generally but little attended to: this is the frequent examination of all annuals as they expand their first flowers, and the pulling them up, unless in habit, form, and colour they are fit to remain for stock. Crowded as annuals generally are in the patches sown in gardens, their true character and beauty are seldom seen; and if among the mass sown, some few blossoms appear more striking than the rest, and the seed of these is considered more worthy of preservation, it is generally too late to take away the worthless without destroying the plants most desired; and the seed so saved from the most select variety is but little better than that from any of the other plants.

'The system now recommended gives the advantage of separation and a power of selection, with the certainty that a selected plant will, by its position as a single plant, not only blossom in beauty and vigour, but afford that abundant harvest of good seed which will amply repay in future years the trifling care thus proposed to be bestowed upon it.'

PLANTS FOR THE GREENHOUSE, AND FOR WINDOWS, ETC.

These are of various kinds, both herbaceous and shrubby, and require to be distinguished from the preceding, because they are exotics, too delicate for open-air exposure in all weathers, and require to be kept in a temperature above the freezing-point. This is done by placing them in a conservatory or greenhouse, which is a light fabric, covered with glazed frames, and, if necessary, heated a slight degree in winter by means of flues or pipes of hot water. The most approved situation of a greenhouse, of the old lean-to form, is against a wall with a southern exposure; and, if possible, placed in connection with a range of artificial vineries or hot-houses. In many instances, a conservatory is connected in a very agreeable way with the parlour of a dwelling-house, by which its beauties are enjoyed without the trouble of going out in bad weather or during the inclemency of winter. All the plants are in pots; and whenever it can be done without risk of injury, the sashes are opened, and free exposure permitted. At the country-seats of various English noblemen, as well as in public gardens, such as those at Kew and Edinburgh, conservatories are formed on a magnificent scale, so as to allow the free growth of even tall trees, such as the palm and other large tropical plants.

The most beautiful greenhouse flowers usually cultivated are camellias, geraniums, fuchsias, orchids, cacti, and azaleas. The camellia, or *Camellia Japonica*, is a woody shrub, yielding splendid rose-like flowers of colours varying from white to red. The geranium is a well-known herbaceous exotic, with clustering bunches of flowers of different colours. The fuchsia, introduced from Chili, is a handsome shrub, of different varieties, yielding exceedingly beautiful flowers, of a bright crimson hue; and the manner in which these flowers depend from the branches, like drops of ladies' ear-rings, has a singularly graceful effect. The cacti are

interesting exotics, distinguishable by their thick and succulent leaves, on which usually grow small and sharp prickles; the flowers are splendid. Besides these, we may enumerate, either for their great beauty of blossom or fragrant odours, the nerium, jasmine, gardenia, daphné, heliotrope, acacia, mimosa, eucalyptus, passion-flower, amaryllis, and calceolaria—the last very beautiful, and suitable for open air in summer.

An airy parlour or drawing-room, with windows facing the sun, may be considered a domestic green-house; and such apartments may be furnished with flowering plants, which will bloom and thrive if certain precautions be adopted.

The cultivation of plants in rooms and on balconies and window-sills, is indeed so prevalent a taste that it should not be passed over in a treatise of this kind. It is, moreover, a department of gardening in which very few succeed; nor is a great amount of success attainable. The conditions upon which vegetation depends are—heat, light, and moisture. Wherever *one* of these is wanting, we have an absence or paucity of vegetation. In the equatorial zone, for example, we have heat and light in abundance, and consequent luxuriance of vegetation wherever the soil and air are moist; but in sandy deserts, where moisture is absent, it is seen that no amount of heat or light can make up for it, for there we have barrenness. In like manner, there is in the arctic regions an abundance of moisture, but heat is there absent, and the vegetation is consequently scanty. In subterranean caverns and mines, we have abundance both of heat and moisture, but the absence of light checks the production of plants. These conditions of heat, light, and moisture are equally applicable to the growth of plants on the small scale. But as in nature, we find many peculiar plants so constituted as to resist special conditions of climate, we may materially simplify our arrangements in cultivation by selecting such plants as are best adapted for those conditions to which our domestic flowers are necessarily subjected.

Our sitting-rooms are inimical to vegetation, not so much on account of the impurity of the atmosphere, or its admixture with gases poisonous to vegetation, as from the extreme dryness of the air, caused partly by the want of those terrestrial exhalations which preserve the atmosphere near the soil in a state of humidity, but chiefly arising from the drying effects of fires and stoves in rooms. We have therefore an absence of one of the elements above alluded to as essential to vegetation—namely, moisture; and no amount of moisture, however excessive, that may be applied to the *soil* will counteract the want of moisture in the atmosphere. The plants which are found to succeed best in the ordinary dry atmosphere of rooms, with least trouble, are the cacti and other fleshy plants that are enabled, by their peculiar structure, to withstand the effects of drought. In addition to these, however, many strong growing plants succeed well with little trouble; such as the hardier sorts of fuchsias, and many of the original species of pelargonium (or geranium), especially such as have scented leaves. The improved varieties of pelargonium, and, in fact, most of the improved races of 'florists' flowers,' are too delicate for domestic culture. Many plants that require a great amount of root-moisture grow luxuriantly in rooms, such as the hydrangea and lily of the Nile. The latter is admirably adapted for a balcony or staircase, being very hardy, and having an imposing appearance, even when not in flower. Mignonette grows well in boxes of earth placed on the window-sill.

The HYACINTH (*Hyacinthus orientalis*) is one of those plants of accommodating nature and hardy constitution, which can adapt themselves to a great change of circumstances, and are thus suitable for domestic gardening. It can be grown in the closest room in the most dense part of a city, without a ray of sunlight, and without a particle of soil; in fact, the neatest and cleanest, and most successful mode of managing these plants, is to place them in glasses of water, from which their roots derive all the materials requisite for healthy growth. It requires great skill, however, to produce in this country the finest flowers of which the hyacinth is capable; and on account of its rapid deterioration in our climate, our florists obtain a yearly supply of bulbs from Holland. The famous nursery-gardens which supply the greater part of Europe with hyacinth bulbs, form quite a feature of Haarlem, occupying the southern suburb of the town.

The common form of hyacinth-glass is well known; there are, indeed, various kinds in which hyacinths grow well; and the form of glass is chiefly a matter of taste and convenience, the great point being to allow plenty of room for the roots: some of the best hyacinths we have had were grown in those narrow cylindrical jars used for preserving anatomical preparations, the bulb merely resting on the top without any cavity for its protection, as in the usual form of hyacinth-glass.

The common hyacinth-glass is beginning to give way to an improved form, called Tye's Registered Hyacinth-glass, which has recently been brought into notice in Scotland by Mr C. Alexander. This glass is shewn in

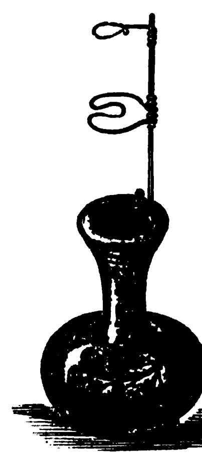


Fig. 4.—Hyacinth-glass.

the accompanying wood-cut, and is manufactured of many elegant patterns. It will be seen that provision is made for supporting the flower-stalk, which is naturally inclined to one side.

The first step in cultivation may be said to be the choice of bulbs. These should be selected as early as possible, an arrangement which will not only insure to the purchaser an extensive choice, whereby good bulbs may be secured, but they will be found to be in better condition than at a later period. In any case, they should be procured before any evidence of growth is visible, otherwise the bulb will become weakened from its tissues giving off their stores of nourishment to the central shoot of leaves. Inexperienced growers are apt to choose those bulbs that have already begun to grow, which it will be seen is a bad practice.

The bulbs should be set in glasses in the month of October, the glasses being filled with water to within an eighth of an inch from the base of the bulb. If placed in the dark for a week or two after planting, the production of root-fibres will be facilitated; but a damp situation is very injurious. After the roots are somewhat advanced, the shoots develop; and during their progress, light and air should be given freely, the plants being placed as near the window as possible. They will succeed well enough, however, on a table or mantel-piece beyond the reach of the sun's direct rays; but in a room

where a strong fire is kept, they should not be much exposed to its drying heat. Some growers recommend a small quantity of salt to be added to the water, but it is doubtful whether this has any beneficial effect. Mr Tye observes: A variety of methods for giving vigour to the plants, and brightening the colours of the flowers, have been resorted to—such, for example, as adding to the water a few lumps of charcoal, a little nitrate of soda, or a small portion of saltpetre; but the following has been found to answer well: Dissolve half an ounce of guano, with so much chloride of lime as would equal the size of a large pea, in a quart of rain-water. Let this mixture stand for a day or two to become clear. Pour about two tea-spoonfuls into the bottle twice a week, after the flower appears well out of the bulb.

The water should be changed regularly once a week from the time of planting to the time of flowering. Soon after planting, it will be found that a quantity of decaying vegetable matter becomes partially detached from the basal portion of the bulb, inside the circle of root-fibres; this should be carefully removed by repeated washings, taking care not to injure the root-fibres, for if broken, they will not be reproduced, as in those plants that have branched roots. When side-shoots appear from the bulbs, they should be pinched off, as they draw away the nourishment from the flowers; but where two trusses of flowers appear, they should both be allowed to expand. When the flowers begin to open, the hyacinths should be placed on a table out of the sun's reach, or otherwise protected from its rays, and in as cool a situation as possible, which will prolong their period of bloom.

There are numerous varieties of hyacinths in cultivation, more than 2000 being enumerated in catalogues; of all shades of blue, red, white, and pale-yellow—single and double.

Several species of fungi are apt to grow in the water and on the bulbs, and are only to be got rid of by careful washing and repeated changes of water.

On the subject of the cultivation of flowers in windows, we find the following useful observations in the *Gardeners' Chronicle:* 'The three principal things requiring consideration are *air*, *light*, and *moisture*. Plants kept in windows naturally extend their branches and leaves to the light, and they thereby become one-sided; and it is wrong to endeavour to make them otherwise by frequently turning them, as the plants will as constantly turn their growth to follow the light, which not only weakens them, but spoils their appearance. As for plants receiving no perpendicular light, it is more natural to spread them out, forming one good face or tier of healthy foliage to the window; for well-balanced heads under such circumstances are almost out of the question. Place them as near the glass as possible; of course windows having a south aspect possess the greatest advantage.

'Judicious watering of plants in rooms is perhaps the most important feature in their management; and it is unfortunately in most cases ill understood, being too often given mechanically, as it were at stated times, whether required by the plants or not; and by a too eager desire for their welfare, they are frequently surfeited to death with water, which is justly termed "killing by kindness," and is practised with success, especially by ladies, from a false apprehension of their wants. In summer, this cannot be easily accomplished, unless the plants are allowed to stand in saucers constantly filled with water, which, by overloading them with juices, will soon engender sickly soft growths, unsuited for the production of flowers or healthy foliage. An exception to this rule is the growth of annuals in pots during summer: they, if well drained, may stand in feeders; but these, whenever used, should be half-filled with fine gravel or sand, which may be kept in any state of moisture. The best and only general rules that can be adopted are—in *winter*, keep plants, not then growing fast, rather dry; in *spring*, increase the quantity with their activity and the sun's power, keeping them in a medium state of moisture; in *summer*, water daily; and in *autumn*, decrease with the length of day, and the returning torpidity of the plants, until the dry state of winter is again reached. All this resolves in the following: Plants, when growing fast, may have free supplies of water, which must be lessened as their growth approaches maturity, and cease, or nearly so, when that is attained, until the return of their growing-season. As regards *air*, similar rules to those given for watering may be followed; and indeed they are analogous. In *winter*, when the plants are not growing, large supplies of air are not so important, enough being usually given by the room-door. As *spring* advances, increase the quantity, carefully guarding against the cold of mornings and evenings, or cutting winds; and if the plants are placed out in the middle of fine days, take care to bring them in before the chill of evening comes on. After the first or second week in May, they may be set outside for the summer; and towards the end of September, or as soon as heavy cold rains occur, they should be placed again in their quarters for the winter, setting them out of doors when fine, or supplying them with plenty of air by the window, until the cold weather and decrease of moisture at the roots bring them to a state of comparative rest. It should be remembered in spring and autumn, that the plants must not go out to-day because they were placed out yesterday, but the weather alone must determine; sudden changes must at all times be avoided. The leaves of plants act as lungs, by which they breathe; if they become dirty, their respiration is impeded; therefore an occasional careful sponging will be useful to them. In spring and summer, allow them the full benefit of genial showers, which will do them more good than any artificial watering. Never use spring-water if soft or rain water can be had; and always let it be about the same temperature as the air in which the plants are growing. It is hardly necessary to mention the removal of decaying leaves and flowers; the last are exhausting as well as unsightly.

'One principal potting is usually required, and afterwards as often as the plants may fill their pots with roots, or seem to require it. The most important thing is good soil, which, if composed of three parts loam, of a fibrous open texture, with a fourth of dung, most plants will thrive in, using plenty of drainage to allow water to pass off readily. Never suffer the surface-soil in the pots to become hard or moss-grown, but let it be loosened occasionally with a piece of stick.

'Succulents are well suited for growing in rooms, as they are not so impatient of either air or water as most other plants; and the abundance of their beautiful flowers renders them objects of interest. Cactus speciosus, Jenkinsonii, flagelliformis and speciosissimus, mesembryanthemums, and flowering aloes, deserve especial notice.'

All that is necessary for successful indoor culture, is attention to the general directions given above. If plants have sufficient air, light, warmth, and moisture, and be potted in proper soil, nothing else is needed, save a little care in keeping them clean, occasionally stirring the upper portion of the soil, turning them regularly to the light, lopping off old wood, pruning unseemly shoots, and removing decayed leaves. It may sometimes happen, notwithstanding all ordinary care, that a few, such as the pelargoniums, may be infested with small green insects, or may otherwise take disease and languish. The former are generally destroyed by a sprinkling of powdered lime, the fumes from a tobacco-pipe, or even, where the nature of the plant will admit, by a thorough drenching with pure water.

Another direction to be borne in mind is, never transfer a plant from one situation to another of a widely different character, without some previous preparation. Vegetables no doubt possess wonderful powers

of accommodation, but there is a limit to this principle; and a plant reared in the hothouse will no more endure the sudden exposure of open air, than the animals of India could live and propagate in Iceland. Thus many of our rarest exotics are permanently injured by *sudden* removal from the stove to the open stand, or from the open air and conservatory to the drawing-room. Plants intended for transferences of this kind should either be taken at the period of their repose, or immediately before their breaking into blossom, if their flowers be the object in view.

Pots and Stands.

Since the main object of domestic floriculture is to improve the taste for what is lovely and ornamental, it should be the aim of all growers who can afford the outlay, to procure pots of as handsome shapes as possible. The common earthenware pot is often very clumsily made, though not of itself an inelegant object; but others may be constructed with ornamental mouldings in relief, or in the form of vases, urns, and the like, which add greatly to the grace of a flower-stand. Pots may also be constructed of stone, of polished slate, as recently manufactured by Mr Beck of London, of cast iron, wood, and the like, and in highly elegant fashions, either to be set on plain shelving or on ornamental stands. Elegance, however, does not consist in exuberance of ornament, and correct taste will avoid all grotesque and fantastic shapes. There is an endless variety of pots; some intended to afford better drainage than the common sort; others whose main object is display and ornament. Whatever be their form, gardeners distinguish them by numbers, thus: The smallest ones are called *thumb-pots;* the next, *sixties,* which are 3½ inches deep, and 3½ inches wide at top; *forty-eights* are 4½ inches deep, and 4½ inches wide at top; *thirty-twos* are 5½ inches deep, and 5½ inches wide at top; *twenty-fours,* 6½ inches deep, and 6½ inches wide at top; *sixteens* are 8 inches deep, and 7½ inches wide at top; *twelves* are 8½ inches deep, and 8½ inches wide at top; *eights* are 9 inches deep, and 9 inches wide at top; *sixes* are 10 inches deep, and 10 inches wide at top; *fours,* 11 inches deep, and 11 inches wide at top; *twos,* 12 inches deep, and 12 inches wide at top—all inside measure. The actual sizes vary, however, with different manufacturers.

Fig. 5.

Stands are commonly made of wood or cast iron; but we have also seen very cheap and pretty ones constructed of a wooden upright, with suspension arms of stout iron wire. Wooden ones, with plain shelving, of circular, or semicircular, or quadrantal forms, make very handsome stands for recesses and corners; those on single uprights, with branches for the support of the pots, are usually constructed of iron wire, or of cast iron painted, and are best adapted for central situations in lobbies and drawing-rooms. It may not, however, be in the power of some to procure flower-stands of either description; and for such, one board placed in the window-recess, so as to bring merely the top of the first row of pots within influence of the light, and a second level with the top of the first pane, will make no inelegant display; the effect of which will be heightened by suspending some light pots from the lintel above, containing such hanging-plants as that called Humility (*Linaria Cymbalaria*). Pendent plants, in fact, form very handsome appendages to a dwelling-apartment, and no amateur should be without some to grace his collection. Of these may be mentioned, as worthy of adoption, Saxifraga sarmentosa, Kangaroo vine, epiphyllous Cacti, ferns, lycopodiums, &c.; and, with a little management, the prostrate verbenas, lobelias, and mimuluses, the trailing mesembryanthemums, with Campanula rupestris, fragilis, hirsuta, and a multitude of plants which resemble them in their habits. Even some annuals, flowered in early spring, as Nemophila maculata and insignis, create a good display when suspended in pots; and many of the tender creepers hereafter mentioned may be trained pendent as well as erect. It must be kept in view, however, that the atmosphere of a room is *usually* too dry for such plants.

Ward's Cases.

It may happen, from the vitiation of the air in towns, and in dwelling-apartments, or from other circumstances, that it is impossible to grow the plants we most wish in open pots. To remedy this, a plan was many years ago devised by Mr Ward, a surgeon in London, of keeping the plants under close glazed frames, in which situation they grow and flourish in perfection. These frames are generally known by the name of Ward's Cases, and may be seen in almost every large town, constructed of every shape and size, according to the taste or means of the grower. By aid of these, any one, whether inhabiting the most humble or the most splendid dwelling, provided it be freely exposed to the sun's light, has it in his power to cultivate a miscellaneous collection of plants, at an expense so trifling, as to be within the reach of the most moderate circumstances. One of these cases, of a very complete structure, is represented, with its collection of plants, in the following figure. On the stand or table is a strong box, lined with zinc or lead, and filled with well-moistened loamy soil, underlaid by a thin subsoil of turfy loam, and this resting on a porous

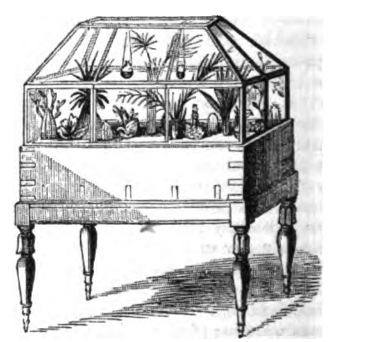


Fig. 6.

stratum of gravel, or broken earthenware. This composition is meant to represent a natural fertile soil, which it does to perfection, the water lodging among the gravel till the wants of the plant in the superior mould require it. Over this box is placed a close-fitting glass cover, which completes the apparatus. The lighter and thinner the glass-frame, and the finer the glass, the better are the plants exposed to view, and the more readily do they receive the sun's light. This plot of soil, with its glazed framework above, forms a little world of itself, in which the plants grow and flourish. When the moisture of the soil within is vaporised by the heat of the sun, it collects on the inside of the glass, and trickles down again, so that the plants are never subjected to irregular or capricious watering. The case is not absolutely air-tight; if it preserves a certain regular amount of moisture and warmth, while it excludes

dust, soot, smoke, and other noxious fumes, it does all that is required. The Ward's Case may be large enough only to cover a single plant, or to become a domestic conservatory.

Cases of the kind described may be used either for indoor or open culture, and answer as well for a little front-plot or back-court as for a drawing-room. They can be also conveniently put up in balconies, or even over the entire window, so that the panes may serve for one side of the conservatory. Many such are now to be seen in our large towns, even in the smokiest and least inviting quarters. This sort of double window, if we may so speak, is admirably adapted for tall plants and flowering shrubs, or for suspending pots, and is altogether a very pretty annexation to a dwelling. Lofty and partially close cases of this sort are fitted for almost every species of greenhouse plant; natives of damp and shady situations, grow and bloom in them to perfection; but the moistened and shaded atmosphere of a small and closely fitted case is destructive to many flowering-plants. Among those most suited for Ward's Cases are many lovely and rare plants, which will amply repay the attention of the case-grower; such as ferns, lycopodiums, and mosses.

Rare exotics need not, however, be sought after. 'The plants to furnish it,' says Mr Ward—who, however, uses cases of *large* size—'can be procured abundantly in the woods in the neighbourhood of London. Of these I will mention a few. The common ivy grows most beautifully, and can be trained over any part of the case, agreeably to the pleasure of the owner. The primroses, in early spring, will abundantly repay the labour of fetching them, continuing for seven or eight weeks in succession to flower as sweetly as in their native woods. So likewise does the wood-sorrel, the anemone, the honeysuckle, and a host of other plants, independently of numerous species of mosses and of ferns. Some of these latter are more valuable than others, in consequence of the longer duration of their fronds, such as *Lastræa dilatata*, and its numerous varieties. There are likewise many cultivated plants procurable at little or no cost, which grow without the slightest trouble; such as the *Lycopodium denticulatum*, the common musk-plant, myrtles, jasmines, &c. All the vacant spaces in the case may be employed in raising small salads, radishes, &c.; and I think that a man would be a bad manager who could not, in the course of a twelvemonth, pay for his case out of its proceeds. These remarks apply chiefly to situations where there is but little solar light. Where there is more sun, a greater number and variety of flowering plants will be found to thrive; such as several kinds of roses, passion-flowers, geraniums, &c., with numerous beautiful annuals—namely, *Ipomœa coccinea*, the species of *Nemophila*, *Convolvulus*, and a host of others: the vegetation, in fact, can be diversified in an endless degree, not only in proportion to the different degrees of light and heat, but likewise by varying the quantity of moisture; thus, with precisely the same aspect, ferns and bog-plants might be grown in one case, and aloes, cactuses, mesembryanthemums, and other succulent plants in another.'

Case-grown plants, after the first preparation, require little or no care; the case need only be opened for the removal of dead leaves, or for a little trimming when required. Plants in open flower-pots are exposed to the vicissitudes of change of climate, and require constant watering; but the plants in these cases seem to be independent of any change of temperature in the air, and water themselves. The moisture rises by the sun's influence from the moistened earth, refreshes the leaves of the plants in its aërial condition, and during the cool of night, falls to the earth again like rain or dew. In this manner there is a constant succession of rising and falling of moisture, in imitation of the great processes of nature daily going on in the fields around us.

Walls and Trellises.

Where it is objectionable to fasten climbing-plants to walls, a light trellis-work of wood or iron wire may be employed; permanently fixed where the climbers are perennial, but movable where they are grown merely for summer purposes. By being removed in autumn, and kept dry, a wooden trellis, originally of small cost, will last for a number of years; while its removal, along with the withered branches of the plant, is a positive improvement to the appearance of the dwelling. Nettings of string or wire make very convenient leaders when other material cannot be had; and these may be woven along the outside of doors and windows, where other frameworks might not be permitted.

Among the *hardy* species adapted for trellis-work and walls are the honeysuckle, the ivy, many varieties of the rose, the jasmine, the small white clematis, the Pyrus Japonica, Lathyrus, or even the hop, where an easily nurtured and quick-growing climber is wanted. For summer purposes merely, a selection from the following genera may be made: Cobæa, several species; Convolvulus; Lathyrus, several; Lophospermum, several; Maurandya Barclayana; Tropæolum, several; Passiflora cærulea.

It has been often remarked that, of all flowering plants, climbers present the most graceful forms which can be contemplated under the open sky; but true as this may be, the tender varieties are not the less graceful when cultivated in the greenhouse. Grown in pots, and sustained by appropriate frameworks, they can be trained to almost any shape, be it urn, vase, obelisk, or pillar—a screen of living net-work, or a fairy arbour. Trellises affixed to the outside of pots can be had of a thousand designs, and they may be constructed of wicker, slender painted rods, cord, or copper wire, which is one of the most pliable and durable of materials. By the adoption of this plan, with frequent prunings, climbers may be made to clothe a trellis not more than a few feet high, and so requiring no larger space than a small shrub, flowering profusely. Climbers are usually not of difficult culture, for we have seen a cottager's window shaded within by a screen-work of leaves and blossoms, more effectually than it could have been by the costliest Venetians.

Rock-work and Aquariums.

If space and means permit, a flower-garden may be much improved by introducing a piece of artificial rock-work and a small pond; because, in connection with these, certain highly interesting plants may be reared, which would not answer on a plain surface. In order to increase the effect, the pond should be at the base of the rock-work, and receive from it the trickling of water which has been conveyed to the summit in pipes. Let the rock-work have a natural appearance, with rugged sides, and perhaps be ten or twelve feet high. Rocks of the same kind and colour should be placed together. A dark cave, penetrating into the thickest part of the erection, is not very difficult to construct; and when encircled with ivy, it will form an interesting object. Rock-plants of every description should be profusely stuck around, and in twelve months the whole scene will exhibit an impress of antiquity far beyond anticipation. The undertaking, when completed, will present a field of varied and interesting study, and more than compensate for all the attention and outlay bestowed upon it. The aquatic and rock plants, which formerly were 'far to seek and ill to find,' will thus be brought within the range of everyday observation. If the situation is secluded and in the country, the wagtail, oxeye, and stonechatter, may be attracted to the spot, not perhaps because they are lovers of the picturesque, but because they find everything here suited to their nature; and

colonies of the wild-bee will soon be seen and heard around the interstices of the rocks. A weeping-willow adjoining one or two mountain-ashes, and some of the hardy varieties of fuchsias mirrored in the lake, will add materially to the beauty of the scene; and if the spot be airy, there might, with advantage, be planted, on the top of an eminence, the *Scottish thistle.*

Among the plants suitable for growing from the crevices of the rocks may be mentioned various heaths and mosses, the Valeriana dioica, Trifolium alpestre, Thymus Chamædrys, Epilobium alpinum. Many plants might be mentioned as suitable for the marshy borders of the pond, as the Acorus, Littorella, Lychnis floscuculi, Saxifrages, Primula farinosa. We should recommend the unprofessional gardener, in replenishing either a rock-work or pond with appropriate plants, to consult a nurseryman skilled in the subject, as soil, air, climate, moisture, and other circumstances require careful consideration. The great drawback of rock-works is, that in many situations they become harbours for snails, wood-lice, and other vermin injurious to gardens.

Of late years, the attention of cultivators has been drawn to the water-lilies—those lovely Naiads that adorn the lakes and rivers with their ample foliage, and, raising their gorgeous flowers with the morning sun, recline them

'In graceful attitudes to rest,'

as the god of day sinks in the western horizon. The use of these plants in outdoor landscape-gardening—especially in lake-scenery, for which their expansive foliage and showy flowers render them so well adapted—has arisen chiefly from the attention recently attracted by the gigantic Victoria regia, the Royal Water-lily of South America, whose botanical peculiarities have been already referred to in this work (SYSTEMATIC BOTANY, p. 90). This magnificent plant, with its gigantic leaves, eighteen feet or more in circumference, and delicate rose-coloured flowers thirty-six inches round, is represented in the frontispiece. Being an aquatic of such huge proportions, it requires for its successful cultivation a special structure, with a large central tank of water; but this may be made available for the culture of other aquatics, and the Victoria regia has thus led to the extended culture of exotic aquatic plants. Many new kinds of these have been recently introduced, especially species of *Nymphæa*, among which there is indeed great variety of colour and form, from the little *Nymphæa pumila* to the huge *N. gigantea.*

Some beautiful designs have been published, shewing the applicability of aquatic-gardening to the imitation under glass of tropical scenery; but we prefer representing here a simple diagram (vertical section) of a

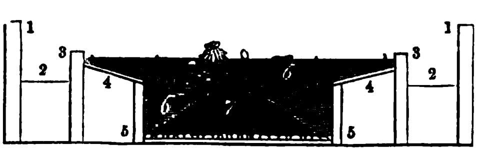


Fig. 7.

1. Outer wall of the building; 2. Foot-path; 3. Outer wall of the tank; 4. Bank of soil; 5. Inner wall of the tank; 6. Water; 7. Mound of soil in which the plants are rooted.

tank for exotic or hardy aquatics, believing that any one can readily adapt it to the size and circumstances of his garden, and render it picturesque according to the means at disposal.

The Parlour Aquarium.

The parlour aquarium or vivarium forms an interesting companion to the Ward's Case; it has for its object the cultivation of aquatic or water plants. It may, in fact, be described as a combination of the Ward's Case and the gold-fish globe; one object being, in addition to the cultivation of plants, the illustration of the mutual dependence of animal and vegetable life. The parlour aquarium consists usually of a water-tight box with glass sides, which may be of various forms, and of size corresponding with the object of the cultivator. The bottom of the box is lined with soil and picturesque fragments of rock, amid which are planted various aquatics, such as Vallisneria spiralis (fig. 8), Anacharis

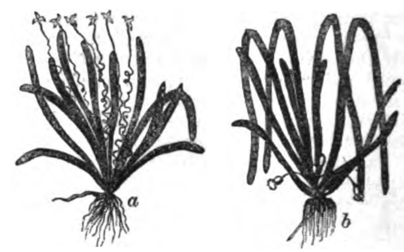


Fig. 8.—Vallisneria spiralis.—*a*, female plant; *b*, male plant.

Alsinastrum, species of Callitriche, and other neat aquatic plants. Aponogeton distachyon, although usually a large and unwieldy plant, is admirably adapted for such cases, when carefully grown for the purpose, as is evidenced by a plant now before us, which was originally raised from a seed in a common gold-fish globe, and within such circumscribed limits continued to produce a periodical supply of its beautiful white flowers, while under the care of a lady who is now botanising among the hills of Northern India. In addition to the plants, gold-fishes, sticklebacks, and other small fishes, may be introduced—even the lamprey, perch, and pike, if the aquarium be large enough; together with fresh-water mollusca—such as species of Cyclas, Planorbis, Limneus, and Physa. The mollusca multiply to a great extent, affording food for the fishes. The plants consume the carbonic acid produced by the animals, appropriating the carbon, and setting free the oxygen in a gaseous state, again to support animal life. It is a great mistake

Fig. 9.

to suppose that a large vessel is required. We have already mentioned incidentally that aquatic plants may be grown well in an ordinary fish-globe; and the above wood-cut represents a simple form of

aquarium which the writer of these remarks has employed successfully for many years—which was in use, in fact, as a miniature botanico-zoological garden long before such things became known to the world under the names of 'aquarium' and 'vivarium.' A glass of the kind here represented, measuring about eight inches across, affords ample accommodation for water-plants, such as Callitriche, Vallisneria, Anacharis, minute Algæ, &c., with mollusca, hydras, cyclops, and other small animal forms; and extensive experience and observation have taught us that a series of vases of this kind will be found more useful by the *microscopical* observer than an aquarium of larger size. Where, however, it is the object to study the habits of fishes and the larger plants, an aquarium of several feet in length, and corresponding depth of water, must be obtained.

Even more interesting than the ordinary aquarium is the marine vivarium, in which are introduced, in *sea-water*, the beautiful red and green sea-weeds, corallines, fishes, marine mollusks, nudibranchs—those graceful *ferns* of the animal kingdom—star-fishes, sea-mice, sea-anemones of varied form and hue, and all the other exquisite forms of life that swarm in old Ocean's caves. In the case of marine productions, it is found much more difficult to preserve the water sweet, and therefore it must be frequently changed or aërated, by being passed through the rose of a watering-pot. In forming the vivarium, sea-weeds must be removed, attached to a portion of their native rock. Where animals have to be taken to a great distance, they are frequently more safely conveyed in moist sea-weed than in sea-water itself. In March 1856, we spent a pleasant afternoon on the shores of the Isle of Wight, and got some prizes in the way of nudibranchiate Mollusca; these were hastily placed in a botanical vasculum among some sea-weed. We crossed to Portsmouth, took the night-mail to London, arrived at Waterloo Bridge at four in the morning, took a peep at the smouldering ruins of Covent Garden Theatre, left our card at Bedford Square for a friend with whom we had promised to dine on our way north, took train at Euston Square at six, and finally reached Edinburgh at ten o'clock the same night. We opened our box, and the nudibranchs were all alive!—those fragile things, that the merest touch of a finger seemed sufficient to destroy. They were placed in our vivarium, and thus had we the pleasure of examining their beautiful forms, and studying their habits, as well as if the Isle of Wight, with its fertile shores, had been brought into the Firth of Forth.

GARDEN-PLOTS IN TOWNS.

The attempt to have a neat and flourishing garden or garden-plot in populous towns is very often defeated by the abundance of smoke and other impurities in the atmosphere; for, as repeatedly mentioned, pure air is essential to the proper growth of plants. It is found, however, from experience, that certain kinds of shrubs and flowering herbs are less delicate in this respect than others; and that, with a reasonable degree of care, open plots in towns may be made to yield a surface of vegetable bloom and beauty. On this branch of flower-culture, so important to many town-residents, there appeared some time ago a well-written paper in *The Magazine of Domestic Economy*, describing the experience of an amateur florist. We take the liberty of extracting from it the following passages: 'When I first took possession of my garden [in town], I found it encumbered with old lilacs and laburnums, the common aster, and other ordinary plants. These I immediately removed: by my west wall I planted a Buddlea globosa and a Virginian creeper; and by my south wall, which was partly covered by a vine, I planted the Jasminum revolutum, the small white clematis, and the Pyrus Japonica. The last grew luxuriantly, and bore an abundance of flowers, which, glowing upon the light wall, enlivened my prospect in winter. I had much of the south sun in my garden, but none of his morning beams reached it, and there was a corner which never had a gleam at all. In this spot I planted a quantity of roots of the lily of the valley, and they flowered well, although late. The laurustine also grew well with me; and I should strongly recommend this pretty shrub, together with the laurel, instead of those deciduous shrubs which we see in town-gardens. The latter become very shabby as they grow old; neither the lilac nor syringa flower well in confined situations; besides this, the untidy appearance of their falling leaves is a great annoyance. My jasmine grew quickly, and, with the clematis, soon covered as much wall as I could afford to them; the great inconvenience of the latter plant is, that it requires frequent attention as to nailing up, and this, where there is not a gardener always at hand, is troublesome; as, although the stem should be cut down within three feet of the ground every autumn, yet the young shoots soon grow beyond a woman's reach. However, it is worth while putting ourselves to a little trouble for the sake of the delicious scent of the flowers of this pretty trailing-plant. As regards perennials, I daresay all who are fond of flowers have endeavoured to nurse the China-rose, and induce it to flower in the town. I have grieved over many a healthy plant which refused to shew a single bud, and watched the gradual wasting away of others, notwithstanding my unceasing care. The common Provence roses, both white and red, flower well in the town; but it is vain to attempt the China—it requires a very pure air; and I do not know any flower whose colour varies so much with the quality of the atmosphere. I am but slightly acquainted with the names given by botanists to the numerous varieties of roses; but I have tried many of them, and found the Tuscan, the rose de Meaux, the Tudor, the little early crimson, and one surpassing them all in beauty, the Bengal celestial (I believe), flower extremely well.

'With regard to spring-flowers, the snow-drop I could not tolerate in the city—the smoke robbed it of all its beauty; the crocus, either the mice or the sparrows would not leave undisturbed; and after replenishing the edge of my border several times, I gave up the matter. The hepatica and gentianella flowered well with me; anemones also I had of very good colours. Heart's-eases pined away after the first year, but they were easily replaced, and they were too ornamental to be relinquished. Then followed the white lily, and a variety of irises, all of which increased fast, and flowered abundantly. The peony I could never persuade to flower; in the first place, it does not blossom well until it has been for years settled in a garden, and I believe its beauty even then is greatly dependent upon the purity of the air. My buddlea was every spring covered with its golden balls, and grew so quickly that I scarcely knew what to do with it. I am surprised this beautiful shrub is not more common: it is perfectly hardy, even as a standard; it will remove well, even when it has attained a considerable size; it is very easily raised by layers; and there is an air of grandeur about it, both as to leaves and flowers, that raises it above the common flowering shrubs of our gardens. But we go on in the old-fashioned manner of planting our gardens. The same varieties of deciduous shrubs are taken, without considering with how much advantage their places might be supplied by those more lately introduced. The magnolia, for instance, grows quickly and flowers abundantly in the city upon a south wall; and the arbutus is not at all particular with respect to situation. The Bignonia grandiflora also does not withhold its scarlet trumpet-like blossoms in the immediate vicinity of a steam-engine. To return to my garden, the glory of which in the autumn was the Lobelia fulgens; I managed it thus: I sank in the ground up to the rim, a large and deep seed-pan; this I filled to about three-quarters of its depth with rich soil, properly

mixed, and planted my roots. As soon as the shoots appeared, I supplied them plentifully with water, and from time to time added more soil. The plants grew luxuriantly, furnishing tall and thick stems, with large and highly coloured blossoms; indeed, the gardener who had assisted me said that he had never seen finer flowers. The sweet-scented marvel of Peru thrived well with me, and the tiger-flower also. Carnations and picotees I tried one year, but was so much disappointed in the result that I gave them up, although very reluctantly, as I believe carnations do not require a very pure air; and I have fancied since that my failure with them arose from some other cause than the smoky atmosphere. Dahlias also, although they flowered very well, I gave up. The Amaryllis lutea flowered well with me when once established, and the Hemerocallis cærulea and flava did the same.'

FLORICULTURAL MONTHLY CALENDAR.

January.—Little can be done in the flower-garden except in open and dry weather; but advantage ought to be taken of favourable intervals to make the plots and borders neat. Propagate, by division of roots, daisies and thrift; protect the beds of hyacinths, anemones, ranunculuses, and tulips, by a covering of coarse litter. Top-dress auriculas, using a compost of light loam and two-year-old cow-dung, mixed with a twelfth each of sea or river sand, and rotten wood. Plant all the bulbous roots that are still out of the ground. Sow mignonette, stocks, and other half-hardy annuals, in heat, using the propagation-pot, by which means the entire number of seedlings—allowing for previous thinning-out—can be transferred, with roots undisturbed, to the plots or borders.

February.—Attend to the foregoing general directions; cut turf for lawns; fork and clean the flower-borders. Plant anemones and perennial herbaceous roots; and transfer others, dividing the crowns, to multiply the species, such as the primrose, single and double, and the polyanthus. Transplant carnations, also the divided roots of campanula, lobelia, lychnis, mullpink, and Dianthus sinensis. Sow, in mild heat, any annual flower-seeds, and auriculas and mimuli, in boxes or pans; also the beautiful Primula sinensis. Excite choice dahlia-roots, placing them in hotbed frames, or in troughs or pots of old tan, or any light moist substance, on the floor of a stove or vinery at work.

March.—Sow, under glass, tender annuals, including balsam-seed, collected from the best double flowers. Plant box-edgings; also evergreen shrubs of every description. Transplant autumn-sown annuals, and protect them till fresh-rooted; as clarkia of every kind, mignonette, schizanthus, &c.; and sow, under glass, stocks, china-aster, clarkia, dahlia, campanula, larkspur, pentstemon, amaranthus, tobacco, and all the hardy annuals. Take cuttings of hydrangea from the tops of the shoots; these, if the buds be full, sometimes will produce a fine flower-head, and the effect is striking.

April.—Plant hollyhocks, carnations, and other biennials and perennials, for flowering; at this season, every herbaceous plant is almost certain to succeed. Campanulas—the tall pyramidal—raised by cuttings in autumn, may now be transferred to pots of loam and leaf-mould; and as the plants grow, they are to be constantly shifted, till they come into pots, wherein they will bloom profusely. If placed in the borders, they require no peculiar treatment. Sow in a pot the seeds of this variety of campanula (seedlings frequently produce the finest plants; they require profuse watering); also the seeds of the pansy, to procure new varieties. Propagate, by cuttings, salvias, verbenas, rockets, and fuchsias. Bud China, noisette, and moss-roses, on dog-rose stocks. Divide the roots of dahlias, either retaining one single tuber with a sprouting eye, or twist out very cautiously a single shoot, so as to detach it from the base, planting it in the smallest pot of sand and leaf-mould; a gentle hotbed will facilitate the protrusion of roots. Sow most of the hardy annuals in the open ground.

May.—This is the season to stock the flower-garden with those plants which have been prepared during autumn, winter, and spring; and therefore transfer, from the propagation-pots, annuals raised in them, by lifting the whole mass, and depositing it in a spot prepared in the border: thus trouble and loss of time are obviated. Sow annual seeds in the open ground for succession. Plant the parterres with groups of fuchsia, calceolaria, petunia, verbena; and at the latter end, form masses of the scarlet and variegated geraniums, as well as of the stage and fancy varieties. Propagate, by cuttings, China-roses of every kind, planting them two joints deep, in a shady situation; also calceolarias of the shrubby kind, Peruvian heliotrope, &c. Propagate, by slips, lychnis, double rocket, pansies, and wall-flower; thin out the superabundant shoots of perennial asters, antirrhinums, pentstemons, phlox, and all luxuriant herbaceous plants.

June.—Propagate, as during the last month, and plant young side-shoots of hardy lobelias, in shady borders, under a hand-glass. The pipings of pinks, placed in sandy earth, are to be closely covered in the same way, till completely rooted. Greenhouse plants may now be arranged in a north aspect; the pots to stand on a deep stratum of coal-ashes. Azaleas, Acacia armata, heaths, rhododendrons, and such plants, are greatly improved by being turned out of pots, and planted with the entire balls in an open peat-border.

July.—Bud roses on wild stocks. A pretty effect is produced by inserting one or two buds of the deep-red China in the common China-rose; the different tints of the two roses are very pleasing. Propagate, by cuttings, the Chinese azaleas, half-shrubby calceolarias, linums, pelargoniums, fuchsias, myrtles, and other exotic shrubs. Layer carnations in sandy earth; peg them near the incision with hooks of fern-fronds. Sow mignonette in small pots for winter; also annual flower-seeds for bloom in September.

August.—Bud roses as before. Plant seedling herbaceous plants; repot auriculas, removing the suckers, and detach the black ends of old roots with the finger and thumb. Sow the seeds of annuals and pansies. Take cuttings of all the fine pelargoniums that are out of flower early in the month; also of calceolarias, shrubby and half-shrubby; and of antirrhinums, pentstemons, which require no heat, but should be placed in a cold frame.

September.—Plant the crocus and other early bulbs. Transplant herbaceous perennials and pinks to permanent beds, if perfectly rooted. Propagate, by cuttings, China-roses in the open borders; also petunias, heliotrope, salvias, geraniums, calceolarias, &c.; they require only a hand-glass and light soil, or slight bottom-heat. Sow auricula seeds in pans in the greenhouse; also clarkia, collinsia, and other annuals, to be preserved in pots all winter. If the pyramidal campanula be out of flower, take up one of the finest roots; break it to pieces, and half-filling a large pot with loam, place the pieces on the earth, fill the pot with loam, and keep it merely protected from frost all winter. Raise every geranium or other greenhouse plant now in open ground, and repot in soil suitable to each. Cut back to low buds the scarlet and other geraniums, and place all the plants under glass, to recover from the removal; make cuttings of the best amputated shoots of geranium. Gradually diminish the watering of all greenhouse plants.

October.—Plant, towards the end of the month, bulbs of the hyacinth, narcissus, and tulip, the common jonquil, and daffodil, and common anemone roots, &c.; also shrubs of every description, though evergreens generally succeed in spring. Hyacinths in pots, filled with a compost of light loam, sand, and vegetable earth, should be plunged to the rims in ashes, or light earth, under the glass of a cold frame; and when the plants begin to grow, the pots should be raised, cleaned, and placed in the greenhouse. Greenhouse plants must now be taken in, and be gradually inured to winter treatment, by the free admission of air and abatement of water. Take up the Persian cyclamen, and pot it in loam, sand, and leaf-mould.

November.—Plant all bulbs, employing much sand about and above the bulbs. Protect fuchsias, if frost threaten. Screened leaves form the best substance to be placed as mulch. Dahlias should be taken up in airy and dry weather, when quite dry and clean: preserve the tubers in well-dried sand.

December.—Protect beds of tulips, hyacinths, and other choice bulbs or roots, with a layer of saw-dust mixed with sand, or with ashes. Saw-dust alone has been found the most effectual protector to the roots of potted plants in frames, the pots being plunged in it to the brims. If dry weather permit, lightly fork the surface of plots and borders; but at anyrate, if it be frosty, scatter some light manures around the stems of shrubs and the more tender plants; it will tend to enrich the ground.

Fruit.

THE FRUIT-GARDEN.

GENERAL MANAGEMENT.

FRUIT-TREES are either grown as independent plants in an orchard, in which case the tree is suffered very much to assume any height or bulk that nature permits; or they are trained upon walls, or constrained to grow in a particular manner upon artificial palings called *espaliers*. In whatever manner the tree is planted, or designed to grow, the tendency of the main stem and branches of the plant is upwards into the atmosphere, and of the chief roots, downwards into the soil. In general, the depth and spreading of the roots are proportional to the height and spreading of the branches, because the roots are the anchorage and food-seekers of the plant, and require a depth and compass of soil corresponding to the bulk of the tree and its demands for nourishment. It is therefore of the first importance not to stint fruit-trees of a depth and breadth of good sound mould adapted to their expected dimensions.

Trees or bushes planted close to walls should have a depth of soil in proportion to the height of the wall. If the wall be six feet high, the border beneath will require to be trenched two feet deep; and so on to a ten-feet wall, which should have at least three feet of free penetrable soil. The principle is, the deeper the soil, the less will the roots straggle. As already said, their tendency is chiefly downwards; and it is only because they cannot get far enough down, that they range abroad. Their object is to absorb nourishment wherever it can be obtained; and, abstractly considered, it is of little consequence whether this nourishment be procured beneath the main stem, or at ten yards' distance. But, practically, the gardener is concerned in keeping the roots from straggling, and interlacing, as with a net-work, the under-strata of his borders, thus impeding his operations, and perhaps robbing his culinary vegetables or flowering shrubs of a portion of their food.

It will therefore be observed that depth of available soil is as essential in fruit-tree culture as in any other department of gardening. Fruit-trees must never be excited by new and undecomposed manure. The material applied both before planting, and also while the tree is growing, should be loam, mixed with a thoroughly rotted compost of dung, leaves, and the like. Some persons, following an old prejudice, place a paving-stone at a certain depth beneath, to prevent the root of the tree from penetrating into the subsoil; but this is only waste of labour; for if the descent be counteracted, the roots will proceed laterally, and penetrate downwards as soon as they can conveniently do so. By giving a proper depth of soil, and keeping that soil in heart, no fear need be entertained for the tree receiving that injury from the subsoil which it was the object of the paving-stones and lined pits of our forefathers to prevent.

When we say that depth of soil is advantageous, it is necessary to guard against an impression being formed that deep planting is also required. In general, the roots of trees should be placed near the surface.

Mr M'Intosh, in his work on *The Orchard*, offers the following caution on this subject: 'Deep planting is an evil much to be guarded against; and many of the disappointments which have attended the fruit-grower may be traced to this cause. As some criterion for the guidance of the amateur, we would say, let every young fruit-tree, of whatever kind, be planted at least three inches above the ground-level—that is to say, let the part of the stem which was level with the surface while in the nursery, be kept three inches above the general surface of the ground when it is planted, and let the earth be heaped up to that height around it, for a couple of feet or so, in the form of a little hillock. Trees of larger size may be rather more elevated. This applies to soils of the ordinary description; but in damp soils the elevation should be still greater. When trees are set in a pit—which should always be a third larger in diameter than that of the extent of the roots, so that they may be all spread out to their full extent, without being doubled or turned round—they should be spread as regularly as possible, and the bottom should be made perfectly level; by this means the roots will have a horizontal direction given to them, which they will afterwards maintain. The intention of this arrangement is to induce them to extend themselves near the surface, and to prevent their extending downwards into a bad or cold subsoil.'

Grafting—Budding—Inarching.

Fruit-trees are propagated by means of seeds, cuttings, or layers. In the case of seedlings, it is always necessary to adopt the practice of grafting or budding, to insure the production of good fruit; and although these operations are usually performed in the nursery, and do not necessarily form part of the amateur's practice, still they are of sufficient interest to merit a detailed description.

Grafting, which is a practice of great antiquity, may be stated in principle to be the union of two individual plants in a growing state, through the medium of the circulating juices.

Gardeners assign various reasons for grafting: 1. The perpetuation of varieties of fruit, which could not be insured by sowing seed; 2. Increasing, with considerable rapidity, the number of trees of any desired sort; 3. Accelerating the fructification of trees which are tardy in producing their fruit; and 4. Changing the sorts of fruit of an old tree, and renewing its productiveness; for when a tree becomes old, but has still healthy and vigorous roots, and it is thought advisable to renew or improve its fruitful qualities, it is cut off across the lower part of the stem, and forms the *stock* on which *scions* are ingrafted, which scions become in time the fruit-bearing branches of the tree. The wild apple-tree, which bears only crabs, too sour to be eaten, forms one of the best stocks on which a graft can be put; and for this purpose it is grown by nurserymen from seeds. The notice of this fact leads to a consideration of what are the radical principles on which improvement is effected by grafting. On this intricate subject we subjoin the explanations of Dr Lindley: 'In proportion as the scion and stock approach each other closely in constitution, the less effect is produced by the latter; and, on the contrary, in proportion to the constitutional difference between the stock and the scion, is the effect of the former important. Thus when pears are grafted or budded on the wild species, apples upon crabs, plums upon plums, and peaches upon peaches or almonds, the scion is, in regard to fertility, exactly in the same state as if it had not been grafted at all; while, on the other hand, a great increase of fertility is the result of grafting pears upon quinces, peaches upon plums, apples upon white thorn, and the like. In these latter cases, the food absorbed from the earth by the root of the stock is communicated slowly and unwillingly to the scion; under no circumstance is the communication between the one and the other as free and perfect as if their natures had been more nearly the same; the sap is impeded in its ascent, and the proper juices are impeded in their descent, whence arises that accumulation of secretion which is sure to be attended with increased fertility. No other influence than this can be exercised by the stock upon the scion. Those who fancy that the contrary takes place—that the quince, for instance, communicates some portion of its austerity to the pear—can scarcely have considered the question physiologically, or they would have seen that the whole of the food communicated from the alburnum of the quince to that of the pear is in nearly the same state as it was when it entered the roots of the former. Whatever elaboration it undergoes must necessarily take place in the foliage of the pear—where, far from the influence of the quince, secretions natural to the variety go on with no more interruption than if the quince formed no part of the system of the individual.' It must be kept in view, however, that we have no very satisfactory course of experiments on record to shew the precise reciprocal influences of the graft and stock. For an instructive discussion of the subject, see Dr Lindley's paper in *Gardeners' Chronicle* of the 6th of June 1857.

Grafting is performed in two principal ways—scion or slip grafting, and grafting by approach, or inarching. The season for the operation is about the middle of March, when the sap is rising and the buds beginning to swell. The grafting should not take place immediately on cutting the scion: after removal from its parent stem, place it in the ground for a few days, so that it may be partially exhausted of its juices, and be more ready to receive the ascending sap from the stock. Keep it in dry ground, and not exposed to the sun. A scion may be brought safely from a distance by being stuck in a raw potato. Before applying to the stock, cut the extremity of the scion afresh.

Tongue-grafting, by which a tongue or slice raised in the sloping cut of the scion is inserted in a corresponding notch of the stock, is the more common method. The young stem of the stock is cut across, so that the scion which is added forms the stem of the future tree. The cut in both pieces requires to be smooth, and the joining so neat, that the bark on one side of the scion must be even with the bark of the stock. Having joined the two pieces, bandage them together with a flat strip of mat, but not so tightly as to prevent circulation or the expansion of the fibre. Over the bandage, plaster all round a handful of soft adhesive material, formed of clay, cow-dung, and chopped straw, taking care not to disturb the united edges. This mass will form a hardened lump, and may remain till the end of summer, when the union has become complete.

If the grafting has been properly performed, and other circumstances be favourable, the scion in two years will be in blossom, and yield a crop of fruit. What its quality will be, must depend on the nature of both stock and scion. If the scion be of a fine variety, it will remain so; and if the stock be well chosen, the quality may be slightly improved. The excellence of the scion, however, is the prime consideration, for it is the part which is immediately concerned in the elaboration of the descending sap or proper juice, upon which depends the flavour and quality of the fruit.

Speaking of the descending sap, it may be here observed that the thickening of this juice does not take place without the aid of heat and solar light; and thus, in cold wet situations, plants seldom produce so much fruit as in warm and dry ones. Cultivators bend the branches in training them against a wall, so as to prevent the too rapid descent of the sap, and to force it to accumulate in those places where they wish flower-buds to be produced. If a ring of bark be taken off a tree in spring, the sap will rise as usual; but when it begins to descend, a protuberance will be

formed just above the ring, occasioned by the accumulation of the sap. This explains why gardeners sometimes ring the branches of trees in order to throw them into fruit.

For an account of the process of *budding*, which is analogous to grafting, we refer to the number on THE FLOWER-GARDEN.

Inarching is an ingenious mode of grafting, by which one growing plant, without removal, is made to strike upon another plant, and thus form a union. It may be performed in various ways, as represented below. For

example, two branches of a tree (*a*) may be bent so as to meet and strike upon a wound in the main stem, by which a gap will be filled up; one growing tree (*b*) either from the ground or a pot, may be led to unite with another; or several suckers (*c*) may be led from the ground archwise to strike upon a point in the stem, thus bringing fresh aid to the productive part of the tree. By means such as these, quickset-hedges are sometimes thickened like a net-work, so as greatly to improve their appearance and protective qualities.

CULTURE OF FRUIT-TREES.

Having disposed of those operations that are common to most fruit-trees, we shall now proceed to describe in detail the various methods of culture adapted to the different kinds.

The Apple.

The apple-tree is of universal European growth, and, as a cultivated fruit, is believed to have been introduced into Britain by the Romans. It was much cultivated in the gardens of monasteries during the middle ages, and from that source the greater number of our cultivated varieties have drawn their origin. The apple-tree, if favoured by a good soil and climate, will live to a great age, two hundred years being not an unusual duration in a fruit-bearing condition. Some orchard apple-trees now existing in Herefordshire are said to be a thousand years old, while others were brought over by the Normans in the time of William the Conqueror.

The varieties of cultivated apples are now innumerable, several thousands being described in catalogues, but all may be classed into three groups—namely, apples for the *table*, or to be eaten raw; apples suitable for *baking* and other culinary purposes; and apples for *cider*. Table-apples are again subdivided into those which will keep, and those which will not. The choice kinds at present include the Ribstone pippin, which will keep till March, but is in its prime about Christmas; the Dowton nonpareil, scarlet pearmain, and Blenheim orange. The Keswick and Kentish codling and Hawthornden are early ripe, but the fruit will not keep beyond October. The nonsuch is a fine apple, and remains good in October. The old nonpareil is in every respect deserving of its title; its flavour is high and musky, and it keeps long; few apples bring such a high price in the market in February. Other choice long-keepers are, the scarlet nonpareil, the golden harvey or brandy apple, the winter pearmain, and the Easter apple, commonly called French crab. The best baking-apples are the Colvilles for early use; the rennets and pearmains for autumn; the russets and Padley's pippins for winter and spring. To this short list, hundreds might be added; but those who can grow what we have enumerated, and bring them to their full complement of bearing, can require no others as stock-trees. It must always be borne in mind, however, that what will succeed well in one garden may not do so in another, and that experience as to soil and climate, independently of advice from skilled neighbours, will in every case be necessary in the proper and profitable conducting of the fruit-garden.

For *cottage-gardens*, where the soil and situation are favourable for the production of the apple, the following sorts are recommended by Mr Thompson: Where the space will admit of only one tree, the best is the Ribstone pippin; where two, the Ribstone pippin and Dutch mignonne; where three, the Wormsley pippin, Ribstone pippin, and Dutch mignonne; where four, the Wormsley pippin, king of the pippins, Ribstone pippin, and Dutch mignonne; where five, the Wormsley pippin, king of the pippins, Ribstone pippin, old nonpareil, and Dowton nonpareil; where six, the Wormsley pippin, king of the pippins, Ribstone pippin, Alfreston, old nonpareil, and Dowton nonpareil; where seven, the Wormsley pippin, king of the pippins, Ribstone pippin, Alfreston, Dutch mignonne, old nonpareil, and Dowton nonpareil. Beyond this, Pennington's seedling and any other good sorts may be added. Mr Loudon observes, in the *Encyclopædia of Gardening*: 'It often happens that one or more trees can be trained against a cottage wall or roof, or against some wall appertaining to a cottage; in these cases, the proper sorts are, Ribstone pippins, old nonpareils, and if a large kitchen-apple be required, the Bedfordshire foundling. In situations liable to spring frosts, which so often kill the blossoms of the generality of apples, the Court pendu plat is recommendable, as its blossoms expand very late in the season. Under less favourable circumstances, where the Ribstone may not succeed, the Bedfordshire foundling will be a hardier substitute, or the king of the pippins, which is still hardier; the northern greening may be planted for late kitchen use. For an autumn-apple, perhaps none in this case is more to be recommended than the Keswick codling.' To these observations, we need only add, that the cottager will do well in all cases to prefer one or two copious-bearing trees to a number of fancy and fickle varieties.

Standards.—Pruning and Training.—Standards are those trees which grow independently in open ground, and are classed as Large and Dwarf Standards. The proper object of cultivation is to give figure to the tree, of whichever kind, and bring it to a fertile or mature condition. Apple and pear trees, as they approach to maturity, develop short *spurs* along the entire extent of the branches, and those spurs are the best in every respect which are produced naturally without the aid of the pruning-knife. But in addition to fruitful spurs, the trees produce a great number of superfluous wood-shoots, which, if not entirely removed, or at least so curtailed as to convert them to bearing spurs, would render the tree almost useless; in short, to effect prolific fruit-bearing, the shoots must be kept in subjection, or in the state of spurs. A recent writer on this subject observes: 'If a tree be a free grower, on a free stock, as the crab, or a strong pippin, from seed, all the leaders will be checked by shortening them back every year to a distance from the point of origin, which varies according to their strength; where they are very strong, the leading shoots should not be reduced more than within twelve or fifteen inches of their base; but when they are weaker, they may be

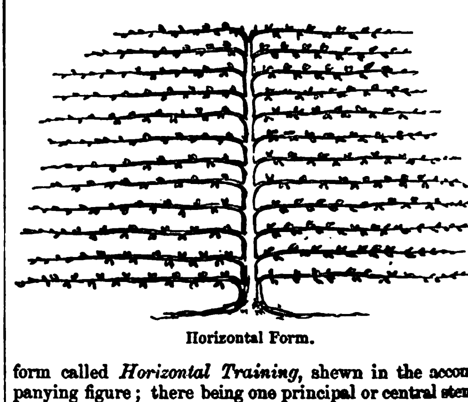
cut to within nine inches. By this means the onward growth of the branch is momentarily arrested, the ascending sap is impelled into the lateral buds, some of which will be sure to grow so slow as to become productive.'

The foregoing directions comprise a view of the theoretical principles of pruning, and afford an excellent groundwork for practice; but those who are strangers to the cultivation of fruit-trees, and, as such, undertake the management of an orchard, will be surprised and perplexed at the anomalies which continually present themselves. It will then be self-evident that gardening cannot, in its routine, be learned from books; that one tree assumes a certain mode of growth; another develops in an order which has not been foreseen or contemplated; one forms its fruitful spurs spontaneously, without solicitation or the adoption of means; while another, in despite of the most rigid foreshortening, continues for years to yield nothing but leafy shoots. Mr George Lindley has given excellent practical directions for pruning in his *Guide to the Orchard*, &c. He observes that 'dwarfs on *crab-stocks* are much more adapted for large and ponderous fruit than standards, as they not only produce larger fruit, but it is less likely to be blown down by high winds. Trees for this purpose should have their branches of an equal strength: those which have been grafted one year, or what are termed by nurserymen maiden plants, are the best; they should not be cut down when planted, but should stand a year, and then be headed down to the length of four or six inches, according to their strength; these will produce three or four shoots from each cut-down branch, which will be sufficient to form a head. At the end of the second year, two or three of the best placed of these from each branch should be selected, and shortened back to nine, twelve, or fifteen inches each, according to their strength, taking care to keep the head perfectly balanced, so that one side shall not be higher or more numerous in its branches than the other; and all must be kept as near as may be at an equal distance from each other. If this regularity in forming the head be attended to, and effected at first, there will be no difficulty in keeping it so afterwards, by observing either to prune that bud immediately on the inside next to the centre of the tree, or that immediately on the outside. By this means, viewing it from the centre, the branches will be produced in a perpendicular line from the eye; whereas, if pruned to a bud on the right or left side of the branch, the young shoot will be produced in the same direction; so that if the branches formed round a circle be not thus pruned to the eyes on the right successively, or the left successively, a very material difference will be found, and the regularity of the tree will be destroyed in one single year's pruning.'

What is here said refers only to the leading shoots which form the figure of the tree; others—side-shoots or laterals as they are termed—are developed, and these require constant regulation. 'In pruning these laterals or supernumeraries, they should be cut down to within an inch of the bottom, which will generally cause the surrounding eyes to form natural blossom spurs; but where the tree is in a vigorous state of growth, branches will probably be produced instead of spurs; if so, they must all be cut out close, except one, which must be shortened as before. In all winter-prunings, care must be taken to keep the spurs short and close, none of which should at any time exceed three inches; cutting out clean all the blank spurs, which have produced fruit the previous summer, to the next perfect bud below.'

It would perhaps be impossible for any writer to improve upon these directions generally; they comprise all the essentials for producing a balanced dwarf standard—that is, a tree low in stature, furnished with ten or twelve regular main branches, proceeding at a short distance from one central stem, each branch furnished from base to summit with fruitful spurs. But experience instructs the pruner not to expect too much, but to watch the figure which the tree affects, and the course of its supernumerary shoots. If it evince a decided tendency to form short spurs naturally at a very early period, he may prune short, as above directed; but if its habit be so luxuriant as to produce wood-shoots after each pruning, it will be wise to defer the summer-cutting of the spring-shoots till the middle of July, instead of performing it at or before midsummer; and then either to snap the shoots or to cut them to a bud situated at least five inches from their base. This pruning, late as is the season, will generally cause each shoot to break its leading eye; in August, therefore, this new shoot is to be checked by nipping off its point; and finally, in September, the spring-shoot is again to be cut at the eye, below the one at which it was first pruned in July. In this way the vigour of the tree will be moderated, and several of the lower buds will probably enlarge, while the leading bud only expands into a growing shoot. If these hints be understood and acted upon, a young pruner will experimentally be taught to apply them, and thereby acquire the tact to discover the constitution of his trees individually, and to coax them into a condition of maturity. At the winter regulation, when the buds begin to swell, it will be easy to discern the fruitful eyes; and where these are discerned, the shoot projecting beyond them is entirely amputated; and this may be done with safety, for spurs, when once fully formed, rarely break into barren shoots, though one of the eyes may do so.

Wall-training.—The circumstance of apple-trees and other kinds of fruit-trees producing fruit only on the outer parts, which are freely exposed to the sun and air, has led to numerous contrivances for exposing the inner as well as the outer stems. One method, as is well known, is the training of the tree in a flat shape against a wall—a plan also advantageous for enjoying the heat, which the wall receives and radiates against the branches. The training of trees upon a wall is a very artificial process, but by no means inimical to their healthy growth, being, on the contrary, conducive to their fertility, while it also facilitates the ripening of the fruit. Much attention is required, however, to carry out the system, and prevent the branches escaping from their constrained situation; and in the annual prunings, the gardener must keep before him the habit of the particular tree, and the form desired. One great point is to induce or preserve equilibrium in the growth of the tree, so as to give it ultimately a symmetrical form. Numerous methods of training have been introduced, but the best for general purposes, and that which has been most extensively employed in this country, is the

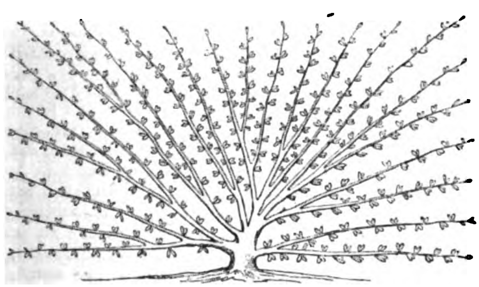


Horizontal Form.

form called *Horizontal Training*, shewn in the accompanying figure; there being one principal or central stem, from which side-branches diverge at right angles, and at regular distances—about ten inches—apart. This form is best adapted for strong growing trees, such as the Ribstone Pippin Apple, or Gansel's Bergamot Pear; but

it may be so modified as to suit the more twiggy kinds. It is thus described by Dr Neill, the 'Father of Scottish Gardening:' 'In order to produce this form, the vertical shoot is, in trees of ordinary vigour, cut back every winter to within fourteen inches of the highest pair of branches; a number of shoots are produced in the beginning of each summer, out of which three are selected; one is trained in the original direction of the stem, and one on each side of it, parallel to the base of the wall. By pinching off the point of the leading shoot about midsummer, another pair may be obtained in autumn. In luxuriant trees, the vertical shoot may be left two feet in length, by which means, and by summer-pruning, four pair of branches may sometimes be added in one season. The great object at first ought to be to draw the stem upwards: when it has reached the top of the wall, it is made to divaricate into two; and the tree thus completed as to its height, is henceforth suffered to increase in breadth only.'

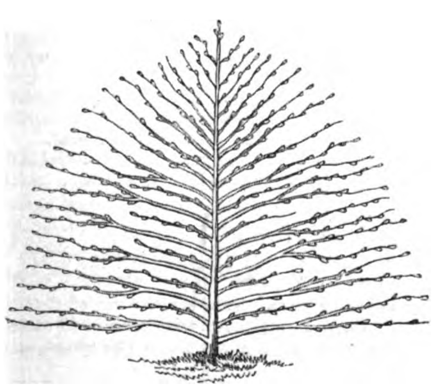
The next form of training we shall notice is called *Fan-training*, from the branches spreading out from a common origin; there being no prolonged main axis as in horizontal-training. The accompanying wood-cut will



Fan Form.

serve to illustrate this form better than a lengthened description. Of course this method can only be adopted successfully where there are lofty walls.

A kind of training called half-fan has been brought into notice, but is, in fact, a modification of the horizontal form, with this difference, that the branches form a more or less acute angle with the stem, which is supposed to favour the natural flow of sap. One of the forms of this method is represented below.



Half-fan.

Espaliers.—These are rails generally formed of upright and cross bars of wood, but sometimes made of cast iron. The best are of wood, and from four to five feet in height. To these the trees are trained as on a wall, with this difference, that instead of being nailed, the branches are usually tied; the fastenings are tar-twine or strips of bast. The situation of espaliers is generally along the sides of walks; and if the trees be carefully trained, they have a neat effect. Care must be taken that they do not prevent the sun and air from reaching the kitchen vegetables. When properly managed and well exposed, espalier-trees 'generally produce excellent fruit, the sun and air having access to both sides of the tree: they commonly afford abundant crops, and the fruit is not apt to be shaken by high winds. Further, they tend to hide the crops of culinary vegetables from the eye, and to render the kitchen-garden as pleasant as an avenue in the shrubbery.'

Espaliers are not necessarily confined to the hedge-like form in which they usually appear. In the Experimental Garden, Edinburgh, examples of more elegant forms may be seen, in some of which the trees are trained on inclined rails, others in a horizontal tabular form, while some trees are made to assume the form of a cup, &c.

The following practical hints on espalier-training, by the author of the *Manse-garden*, appear so eminently useful, that we take the liberty of giving them a place here. First, as to cultivation: 'Have the ground well trenched and manured [taking a crop of vegetables the first season], and plant the trees three or four feet from the walk, and twice as near to one another as they should afterwards be when full-grown. The reasons for this close planting are, that the value of a few crops is more than the expense of the trees; your rails are sooner covered; and when the trees begin to meet and incommode one another, you can then, having ascertained their various qualities, give scope to the best, by diminishing or rooting out the less worthy. For one or two years after the meeting has taken place, you may delay the pain of execution by allowing the young shoots to pass one another on the opposite sides of the rails. To incur no more expense than is necessary, the stakes may be placed two feet apart, in which case the annual shoots will require to be conducted from one resting-place to another by pieces of lath or wild-brier, or willow of two years' growth. These conductors require a firm and separate tying, distinct from that which fastens more loosely the living wood; they thus give strength to the rails, and provide for straighter training than is commonly done by having the stakes twice as thickly set, and, consequently, at double the expense of timber.

'Supplementary to both wall and espaliers is the following device, which has proved eminently successful: Supposing that you have more garden-ground than is necessary for the supply of vegetables, and that some part of it may be spared for a green shady walk amidst shrubs mingled with standard fruit-trees, on the south side of a row of evergreens, impervious to the eye, let a dry stone-wall be raised to the height of four or five feet, and coped with large stones, merely for strength and durability. Plant this on the north side with ivy, to assist the screen of shrubs, and in a short time not one stone will appear. From the south side take away all the good soil to a depth of two feet, a breadth of five feet, and a length equal to that of the wall, which may be sixty or a hundred feet, as you find convenient. This excavation, it is to be understood, runs close by the building, the foundation of which must of course have been secured by perhaps a foot of depth, and which will yet be uninjured, as the stones that cast up in removing the earth will immediately be thrown to the base in room of the materials taken away. Thus an effectual provision is made against the springing up of docks, nettles, or other troublesome weeds; the earth removed will be an invaluable treasure, whether for making compost or helping a thin soil; and the excavation itself will afford a most convenient receptacle for the immense quantities of stones which occur in trenching or raking the garden. Suppose the filling up in this manner to be nearly completed, let a row of large thin stones, set on edge, run along the southern

boundary, and rise two or three inches above the surface of the ground. This will serve to keep the mass of stones distinct from the earth, that there may be no mingling in the process of digging. You have then on the one side of this excavation the low edging, and on the other a wall of four or five feet; and the design is, in the course of time, to fill up, with the riddlings of the garden or with clean stones, in whatever way, the whole space from the summit of the low edging to the top of the wall, to present an inclined plane facing the south, and nearly at right angles to the rays of the sun. On this [which is, in reality, a mound leaning against a wall] fruit-trees are to be trained. Before the bank is completed to its proper slope, the trees may be planted along the southern boundary, and trained for two or three years upon poles laid from the edging to the top of the wall, according to their future destination. When the surface of the sloping bank is raised within an inch or two of its proper height, let a layer of coarse sifted gravel be laid on the top. This will much improve the appearance, and increase the reflected heat; and being free from small sand and earthy particles, will give no birth to annual weeds.

'For the purpose of training, should peaches or apricots be planted, a close trellis will be requisite; but apples or pears will require nothing more than common espalier-rails laid on the gravel, and held in their places by two slight spars running across, one at the top, and the other at the bottom. In the meantime, the ivy produces a beautiful and beneficial effect, surmounting the wall, and adding to the closeness of shelter caused by the evergreen shrubs. It should be clipped along the top after the manner of box-edging. Nothing can exceed the real snugness of the trees so placed, or the beauty of their glowing blossoms spread out under the eye; and the quality of the fruit comes fully up to the theoretical advantages with which it is favoured. The heat is undoubtedly much greater than that of the best wall; and the open flowers find, in their humble height, a shelter, like the daisy of the field, from the sweeping blast, which often scatters the petals of a higher tree like a shower of snow. Experience has fully proved the suitableness of this contrivance to all elevated situations. In some places very low and warm, the heat, so powerfully reflected, might possibly be too great; but in that case, figs and nectarines might be so exposed, and would certainly take all that they can get.'

The Pear.

The pear-tree, like the apple, is found in a wild state in all parts of Europe, and has been similarly domesticated and improved into many fine varieties. The tendency of the tree is to a handsome pyramidal form. It is much longer in attaining maturity than the apple-tree; and on a dry soil, it will survive and continue fruitful for centuries. The tree may be propagated by seeds; but grafting is necessary to insure good fruit.

The observations already offered respecting soil for apple-trees, apply equally to the pear. The pruning, however, is different, for the pear is a very independent growing tree, and, as a standard, will assume its own natural figure in opposition to all restraint. All branches which lash one another must be removed; but, unless the pruner cut and deform his trees in his attempts to create fruitful spurs, there will seldom be a redundancy of wood. A little foreshortening or disbudding in the spring and summer may be useful; but in general, as the pear can seldom become fruitful under seven or eight years from the grafting or budding, it will be prudent to watch the gradual development of the natural spurs, and to cut back the laterals to them when formed, and not before. Mr Knight pruned very little, shortening the main shoots occasionally, not sooner than July. He says: 'I would recommend the knife to be little used upon the young pear-trees, particularly upon the horizontal branches. As a general rule for pruning trees that are to be kept low in gardens, I recommend the upright shoots to be shortened about the beginning of July.'

Many varieties of pear are enumerated in catalogues, all differing from each other in their qualities, time of ripening, or other particulars. Among the finest sorts may be mentioned the Jargonelle, Marie Louise, Beurré de Capiaumont, Muscadelle, Bonchrétien, St Germain, Rousselet, Wilding, Beurré Diel, Glout Morceau, Easter Beurré, and Beurré Rance. The word *beurré*, which here occurs several times, is from the French word for butter; and that, as well as the other names, shew how much we are indebted to our continental neighbours for perfecting this delicious fruit. The summer, autumn, and winter Bergamots are not excelled for rich muskiness of flavour. For a large supply, where much care is not given, the jargonelle will be preferred. The pear requires a warmer climate than the apple; hence some of the finer sorts, which grow well as standards in the south of England, will require a wall and shelter in northern or more keen situations. Any sorts worth cultivating should have a rich aromatic flavour, and be either of the melting kind (*beurré*), or firm and crisp, like the winter Bergamots.

Orchards.

An orchard is a piece of ground specially devoted to the rearing of fruit-trees, principally apples and pears, and is frequently an appendage to the English farm and manor-house. It should be a well-fenced enclosure, and if there be room for choice, its situation ought to be on the side of a dry knoll sloping to the south; the best soil is a fresh sandy loam, of eighteen inches in depth or upwards, reposing on a subsoil of dry gravel or rock. If the ground be wet, it must be thoroughly drained in the first place, as no fruit-tree can answer its purpose if the soil be otherwise than dry.

Shelter is necessary to orchards against the autumnal south-west winds. This is best obtained by high hedges or forest-trees planted on that side. Winds from any other quarter need not be so much dreaded. Sheltering hills at some distance are advantageous; but it must always be kept in view that a free exposure to light and air is very necessary. Many orchards are almost barren, and the trees covered with lichen, from their being too much sheltered, and deprived of a free current of air.

If an orchard is a pasture for sheep, cows, or other cattle, the trees to be planted in it must be standards—that is, trees trained with a clear stem six or seven feet high, from the top of which the branches diverge, out of the reach of cattle. Sometimes the stocks are first planted, and when fairly established, are *worked*—that is, grafted or budded at the desired height.

If an orchard is to be formed out of an arable-field, the ground may be prepared by the plough, laid into bands or ridges of eight yards wide, the trees to occupy the middle or crown of each ridge, these lying south and north. The trees should be planted in right lines, five, six, or eight yards asunder; and the whole area surrounded by a hawthorn hedge. When the trees are planted—which should be about the end of October—the ground may be laid down with a crop of barley or oats, with grass and clover seeds in the spring, and so remain.

If an orchard is to be formed in a grass-field, the ground is drained, if necessary, and enclosed with a hedge and ditch as above. The trees are either planted in trenched pits or in trenched borders—that is, borders six feet wide are traced south and north, and regularly trenched fifteen inches deep, the turf being turned to the bottom. Along the middle of these borders the trees are put in at the distances already mentioned. This done, the broken ground is sown down with grass-seeds, and the trees staked and protected against cattle, if

they are in any danger. The pits, six feet square, are trenched and planted in like manner. In planting the trees, the ordinary care must be bestowed as well in taking them up as replanting. Each should be set on a little mound of the finest of the soil, on which the roots should be regularly spread, and kept near the surface —for deep planting must be carefully avoided; the uppermost fringe of roots should just be within the turf, but no deeper; and they should be encouraged to take a horizontal rather than a downward direction. Orchards planted in either of these methods answer very well, if care is taken of the trees till they are fairly established, and can protect themselves.

The fruits chosen for such orchards are apples, pears, plums, and cherries, and of these, such varieties as are known to thrive, and are most fruitful in the neighbourhood; for all fruits are not equally adapted to the same locality, and this is a point deserving the serious consideration of the planter. Orchards of this kind are planted chiefly with a view to the service of a family, any redundance being sent to market or sold on the trees to the fruit-monger; but when fruit-trees are planted as a special source of profit, a very different plan requires to be followed.

An acre or two of suitable land, with a proper exposure, is fixed on; the whole is trenched fifteen inches deep, and thoroughly drained, if necessary. The surface is levelled, and laid into beds ranging south and north, and about twelve feet wide; along the middle of these the trees are planted, and the intervals are occupied by two rows of small fruits—such as gooseberries, currants, or raspberries. Some of the intervals may have a row of filberts introduced, which, when kept as low bushes, are as profitable as any other kind of orchard-fruit. Such an orchard is intended to be a perfect thicket of fruit-trees: all, whether yielding large or small fruit, must be kept as dwarfs, and trained in the *bush-form*. Of course, the sorts which are naturally of a dwarfish habit are preferred, and if not dwarfish by nature, they must be made so by art. The bush-form is obtained by encouraging the lateral growth of the branches, and stopping those which have a tendency to grow upright. A sufficient number of branches is gained by pruning while the trees are young, and so disposed that they may aggregately form a rotund, compact, but not overcrowded head, shading a circle twelve or fourteen feet in diameter, more or less, according to the fruitfulness or individual strength and habit of the tree. This close planting and low stature of the trees render them a shelter to each other, both against the frosty winds at the time of flowering, and against the equinoctial gales of autumn. In dry summers, a mulching of half-decayed littery-dung is spread under the trees, and hoed in during the winter. Strawberries are introduced when the trees are young, but the ground must not be exhausted by surface-cropping.

The success of such a fruit-garden depends very much on a proper selection of the kinds, and on the skill of the manager in keeping the trees fruitful and dwarfish.

In Herefordshire, Devonshire, and adjoining districts in England, orchards are maintained principally for manufacturing a beverage from their produce. *Cider* is the liquor made from apples; the trees in most estimation for the purpose being the New Foxwhelp, the Wilding, the Cherry Pearmain, and the Yellow and Red Norman. When the ripened apples have been shaken from the trees, they are allowed to remain in heaps for a month or so on the ground, to become mellow; after which the process of manufacture into cider commences. *Perry*, or the liquor from pears, is also a pleasant and wholesome beverage, and in some instances almost approaches the quality of sparkling champagne. The most austere varieties of the pear, unfit for the table, answer best for this purpose; and it is thought that a mixture of the wild pear with the cultivated sorts makes a peculiarly fine liquor.

Quince and Medlar.

These two fruits are more botanical curiosities than useful inhabitants of the fruit-garden.

The *Quince* is classed by botanists with the apple and pear, and these are often grafted on quince-stocks, which confirms their consanguinity. It is said to be a native of Eastern Europe, and to grow wild on the banks of the Danube. It was introduced into Britain from the isle of Candia, but is not much used—the fruit in its raw state having a peculiar disagreeable smell and an austere taste. It is sometimes employed to give flavour to apples in pies and tarts, and is occasionally made into a marmalade, which is much used in the south of France, where the quince is extensively cultivated. The *Medlar* is also a native of South-eastern Europe. It has considerable flavour, but this is seldom developed, even in its ripe state, on the tree, and the fruit is therefore gathered and laid aside until it begins to change or decay, and then only is it fit to be eaten.

Peach and Nectarine.

Both are natives of the East, introduced from Persia in the year 1562, and extensively cultivated since that

period. Each exhibits two leading sub-varieties—namely, those in which the stone parts freely from the pulp, or *free-stones;* and those with flesh adhering to the stone, and therefore termed *cling-stones.*

The peach and nectarine (*Amygdalus Persica*) can be raised by sowing the stones, and excellent varieties have been so obtained; but as there is no certainty of what a seedling may ultimately become, it is not prudent to trust to this mode of propagation. Budding must therefore be resorted to. The peach and nectarine are seldom grafted; it is usual to select buds of trees that are approved bearers and of fertile habits, and to insert them into young vigorous stocks of the plum or almond. Nurserymen raise their trees in this way, preferring the plum-stock; the operation is performed late in July or early in August. The buds swell, but remain torpid till the spring of the following year, at which time the head of each budded tree is cut back to an inch above the inserted bud, which then expands, and forms one or more shoots; in general, the nurseryman prunes and trains them into form during the two succeeding years, when they are sold as trained trees. Either horizontal or fan training—as already described under the apple—may be adopted for the peach and nectarine, which must always be grown on a sheltered wall.

The peach produces its fruit upon the spring-wood of the previous year, and occasionally, also, if the habit of the tree be very vigorous, upon secondary shoots from that wood; but this is by no means desirable under ordinary circumstances, for it proves that the tree is too luxuriant in young wood, which, being developed after midsummer, can scarcely become duly mature. A tree cannot be expected to produce or support a crop of fruit in a period short of four or five years from the budding; but during that period the art of the gardener should be employed to lay in six or more regular branches to the right and left, which will form the skeleton or figure of the tree, and remain the

permanent supporters of the young bearing-wood. In the fan-method of training, secondary fruitful shoots are permitted to form at the under as well as the upper sides of these main branches; but in horizontal training, the fertile secondaries are led off from the upper sides only; all those which break from the front, or from the back next the wall, or from the under side, are obliterated as they appear, either by pinching them off with the finger and thumb, or by amputation with a sharp knife. The quantity of wood to be retained, year after year, so as to obtain a regularly increasing proportion of fruit, without redundant wood, is chiefly regulated by the judicious use of the knife in disbudding.

We will suppose the example of a tree trained in the nursery during two years, then planted in October against a wall fronting the south or south-east, and cut back in February following, so as to leave all its branches about six inches long. The shoots of the first spring form the bases of the permanent branches, and are to be nailed, as they advance, in the most regular order, leaving them at their full length till February of the second year, when the strength and condition of the tree are to be consulted. As a first rule, we are taught, and experience sanctions the rule, 'that every shoot is to be shortened in proportion to its strength, by pruning to the point where the wood is firm and well ripened, by which all the pithy wood is removed, causing a supply of that which is better ripened for the ensuing year.' But in order to facilitate the ripening of the wood, it must be trained thin, retaining those shoots only that may be required for the ensuing year. After two years' growth in a good soil, we may reasonably expect that six or eight permanent shoots, a yard or four feet in length, will be formed and trained in, on each hand, and that all these branches are furnished with three or more secondaries, laid in at nearly equal distances from one another, and which, by the end of June, may be a foot or more in length. The tree will continue to grow till the end of August; but disbudding must be effected repeatedly, so as to leave it in the form and condition just described. It has then become a bearing-tree, which condition implies a series of strong woody branches of two, three, or more years old, that have produced other shoots in the spring, which, when ripe, are of a deep reddish-brown tint on the sunny side. These latter are the fruitful shoots, and they never bear twice; but if neglected, run on to an uncertain length, sending forth other weak laterals, which might indeed bear a little fruit, but such as could never compensate for the ruin, or at least disfiguration of the tree. It is a maxim among good pruners, that a peach-tree should be *green* throughout or all over—that is, every space, even close to the main stem, has one or more leafy and fertile shoots. This maxim would be violated in two seasons were all the shoots permitted to extend themselves.

The bearing-shoots, therefore, must be shortened to twelve or fourteen inches, if strong; and the weaker to eight or ten inches, or even to half that length, if very slender. The pruner should cut sloping from behind. In furnishing a tree, it is not needful to cut away the wood-shoots as useless; because by pruning back to an eye seated rather low on the shoot, two good fertile shoots may be provided in lieu of a barren one. A single sharp-pointed eye is the origin of a wood-shoot; the blossom-bud is more bulky and rounded; but by deferring the winter regulation till late in February, the condition of the two will be no longer doubtful.

When it has once been so pruned, the leading branch will break its extreme bud, which will thus elongate that branch; and the fruitful laterals will also develop several minor shoots. It is from the last that a selection must be made to effect two objects of the greatest importance. The first is, to attract the sap along the entire shoot, in order to nourish the young fruit upon it; and this will require that the shoot at the extreme point, or at least one beyond the uppermost fruit, be permitted to extend itself, and be nailed securely to the wall, when it shall have acquired some strength and toughness. The second object is, to provide a shoot to succeed the one now bearing fruit; and in doing this, the lowest should be selected, because it will, by its situation, replace the present shoot in a manner most conformable with the gardener's maxim before adduced, and tend to keep the tree compact and fertile. A third shoot ought also to be retained to guard against emergency or accident; all the others should be removed by disbudding early in May. In July also, a general regulation must take place; when, by removing useless shoots, and nailing those retained, the fruit will be duly exposed to the sun's rays. Thus the growth of shoots and fruit proceeds; and if regularity and order be maintained, the tree will, year after year, elongate, and add branch to branch, retaining complete verdure throughout. A few lines from *The Guide*, by G. Lindley, will suffice to complete our concise directions: 'Should young shoots, indicating extraordinary vigour, anywhere make their appearance, they should be immediately cut out, unless where a vacant part of the wall can be filled up; because an excess of vigour in one part of the tree cannot be supported without detriment to the other. Peach-trees, when in a state of health and vigour, generally throw out laterals from their stronger shoots; when this is the case, they should not be cut off close, but shortened to the last eye nearest the branch; and if there is room, one or two of those first produced may be nailed to the wall, or the middle shoot may be cut out, leaving the two lowest laterals, and allowing them to take its place—thus frequently obtaining two fruit-bearing branches, when the main shoot would in all probability have been wholly unproductive.

'In the thinning of the fruit of peaches and nectarines, and indeed any other drupaceous fruit, it is necessary to proceed with caution, as it is apt to fall off after having attained a considerable size. In order, therefore, to secure a crop, it will be the best way to thin them at three separate times: the first, as soon as the fruit is of the size of a hazel-nut; the second, when of the size of a small walnut; and the third, as soon as the stone has become hardened; after this, it rarely happens that either peach or nectarine falls off before it is matured.'

Peach-trees are liable to be molested by insects and mildew; the former are usually species of Aphis, commonly called *green-fly*. In some cases the trees attacked suffer to an extraordinary degree, insomuch that the crop dwindles and the growth of the trees is checked—three or four distinct broods succeeding each other. Fumigation and washing with tobacco-water are the only remedies.

With respect to soil and preparation of border, what we have said respecting the *apple* applies strictly to the peach. As wall-peaches must have a border, we can devise no plan more effectual or simple than that of clearing out a space of the required length, of eight to twelve feet in breadth, the depth of soil at the wall to be twenty inches, sloping to fifteen inches—making a fall of five inches from back to front. The bottom of the bed being properly prepared, the bed itself should consist of the rich, but not clayey loam and turf, of a common or pasture, having in it no manure whatever. The trees may indeed be top-dressed every winter with littery manure a yard or more round the boles, and so deep as to protect their roots from frost. It will also be a great preventive of drought in summer; and of this any one may satisfy himself by raising the mulch in the very driest weather, when the soil under it will be seen black and moist, though in other parts it be parched to aridity. The fruit is said to be one month accelerated, and its value proportionably enhanced, by growing a tree in a pit of twenty-four feet long, sixty

inches deep at the back wall, and thirty inches at the front. The lights will thus obtain a sufficient slope, if their length be seven feet. Hundreds of fine fruit can be produced in July or August by one tree; but great watchfulness will be required about the period of blooming, to check the ravages of the aphides in their earliest approaches; by three days' neglect, we have seen the destruction of a crop, and the ruin of all the bearing-wood of the year, in despite of every usual application. A strong lining, twice renewed between February and June, will greatly accelerate the advance of the fruit.

Selection of a few of the finest Peaches.

Bellegarde, or Galande.*	Noblesse.*
Chancellor.*	Royal George.
Late Admirable.	Rosanna, or Yellow Alberge.

Nectarines.

Elruge, or Claremont.*	Violet Hative.*
Fairchild's Early.	Early Newington.

The trees marked thus (*) are suitable to the Highlands of Scotland.

Some interesting details have been given by Mr H. Bailey (*Gar. Chro.*, April 4, 1857) of the system of peach-culture adopted at Montreuil, the village celebrated for producing fine fruit for the supply of the Paris market. The walls are eight or ten feet high, and white, being coated with plaster; the soil, a brown calcareous loam, resting on limestone rock, and therefore well drained, which is essential to peach-culture. Large heaps of the sweepings of the streets of Paris were lying in the lanes, ready to enrich the peach-borders; but the point we wish particularly to call attention to is, that the walls on which the trees are trained have a broad projecting eave of thatch, which is made still wider during the prevalence of spring frosts. In England, and especially in Scotland, our wall-fruits suffer so much from spring frosts, that any hints on this subject are valuable. In some of our best gardens, movable canvas screens are employed; and by means of these, combined with the Montreuil coping, we may almost effectually guard against all such injuries.

The Apricot.

The apricot (*Prunus Armeniaca*) is a native of Caucasus and China. It partakes of the habits of the plum and peach. It is multiplied by budding, either upon the common plum or the mussel plum. Lindley says that it is usual to bud the *Moor-park* upon the former; but he is persuaded that the tree would be better, and endure longer, were it budded upon the mussel; and if he be correct in this, we may safely assert that all the best apricots will succeed upon that stock without having recourse to any other. The operation of budding, like that of grafting, may be most readily acquired by observing the practice of a good budder. The season of budding is comprised between the third week of July and the 16th of August, and showery weather is propitious. The buds should be selected from shoots of the spring-wood; and in taking them off, a piece of bark one inch and a half long should be retained, from which the strip of wood it contains ought to detach itself freely, without bringing with it the eye of the bud. This eye or point is a vital organ, without which a bud cannot grow. This remark applies to every kind of bud, whether it be that of the apple, pear, peach, or any of their kindred; or of any ornamental tree or shrub which admits of being thus propagated.

The best varieties of apricot are—1. Breda, a very rich juicy fruit; 2. Moor-park, of high flavour, and also pretty large; 3. Royal, a French sort, earlier than Moor-park; 4. The Roman, hardy, and an abundant bearer, but the fruit is fit only for preserving.

As to pruning and training, when the figure of the tree is formed by having three or four branches proceeding from a main stem, each is shortened, soon after the leaves fall, to six inches, in order to obtain new branches. These are secured to the wall in May or June, at five or six inches' distance from one another, removing all supernumeraries. At the second winter-pruning, the leading shoots may be cut back to ten inches, the others growing upon them to six inches, more or less, as position and strength indicate. In May or June following, more wood is laid in from each branch; and thus, by disbudding and winter-shortening, a regularly formed head is obtained, upon the shoots of which short fruitful spurs are duly and progressively developed. In all winter-prunings and curtailments, the longest shoot that is retained ought not to exceed eighteen inches in length; thence diminishing, according to the strength of each, to nine, or even six inches.

The Plum.

The common sloe of Britain may be cited as an example of the genus *Prunus;* but those rich and luscious fruits which have been so long cultivated throughout Europe are of Eastern origin, being varieties of *P. domestica*. Plums are propagated by budding upon the common plum-stock; and for standards, the insertion is made nine inches from the ground, when, under favourable circumstances, the buds will produce vigorous shoots, standard high the first year. Open standards require little attention; they should be divested of all the superfluous shoots by pruning them out close to their origin, just before the season of spring-growth. But wall-trees and espaliers are to be treated as espalier pear-trees—that is, by training them with a central stem, and a series of horizontal branches proceeding from it on each side, nine inches apart. These branches are not to be shortened; and the spurs which form naturally upon them are to be kept short and compact as they advance in length. Artificial spurs may be obtained by July foreshortening; but as fertility is promoted by whatever checks the luxuriance of the wood, it will, we think, be preferable to train in the supernumerary laterals, depressing them below the horizontal level till some natural spurs are formed near their origin, and then to cut the shoots back to the lowest spur.

The plum ripens in September and October. Of the earlier dessert-plums, the Green Gage and the Orleans are the best. Coe's Golden Drop comes into season in October; and for preserving, we name the Winesour, the two varieties of Magnum Bonum, and the Damson. The Imperatrice is the best late plum, being delicious in November. Lawsons' Golden Gage Plum is a beautiful fruit, which is beginning to come into notice. The Victoria is also a handsome sort, as frequently shewn at our horticultural exhibitions. Plums are used at desserts, in tarts, and preserves; and, when dried, form the well-known *prunes* of the fruiterer. The fruit of the sloe (*P. spinosa*), when ripe, makes a good preserve.

The Cherry.

The cherry-tree, or *Cerasus*, has been known as a cultivated tree for at least three centuries; orchards, the produce of which was sold at a high price in the year 1540, existing to a large extent in Kent. This circumstance conferred the name of Kentish cherry on that peculiar kind. There are between 200 or 300 varieties, among which the best for general cultivation are the Kentish, the May-duke, and Morello. All may be grown as standards, but the May-duke and Morello produce larger fruit when trained against a wall.

Standard-trees form their own spurs, and require only a little thinning out of superfluous branches; but wall-trees must be treated as the apricot and plum, avoiding, however, to shorten the leading branches. The Morello requires a somewhat different treatment, because it not only bears on spurs, but, like the peach, on young wood of the last spring. Mr Rogers offers some remarks, which are deserving of attention. In

the gardens of which he had the charge, 'a north wall ten feet high had a border twelve feet wide, and very shallow, reposing on loose or rubble rock. The soil was a dark hazelly loam, of rather inferior quality: the roots were very near the surface, those nearest the stem actually above it. Five trees were originally planted, but subsequently the second and fourth were removed, leaving the centre tree at thirty-two feet from the end ones. Even at this distance the branches met; and in their progress, being kept very thin of leaf-bearing wood, the crops were magnificent.' The trees were simply planted on the natural surface of unprepared ground, without any manure or deep trenching. 'Neither was this border ever dug with spades, but slightly stirred with blunt forks, and having a little well-rotted horse-dung bestowed every second or third year. There cannot be a more mistaken notion and injurious practice than overloading and poisoning the fruit-borders with rich dung. In the early training of the Morello, the knife should be used freely, to gain a sufficient number of leading branches—thinning out the laterals, but never shortening them.'

The cherry-tree grows to a large size, and its wood is highly valued by turners and musical instrument-makers, from its suitableness for being bored and formed into smooth tubes; in the luxurious East, it is much used for the tubes of tobacco-pipes. The fruit of the cherry seems less impaired by growing in a wild state than other garden-fruits. In Scotland, the wild cherries, called *geans*, are small, but of fine flavour; and in Germany, the favourite liquor, *kirschwasser*, is distilled from the juice of this species of fruit. The liquor called *cherry-brandy* is made by putting the best black varieties in brandy. *Noyeau* is a liquor flavoured by the kernels of the *C. occidentalis;* and a large black cherry is employed in the manufacture of the *ratafia* of Grenoble. The *maraschino* of Zara is made from a peculiar kind cultivated in Dalmatia.

The Currant.

The currant is a native of Britain. Currant shrubs prosper only in cool climates, and they are somewhat arbitrary in their choice of a situation even in our own moist country; they grow to an astonishing perfection in the rich moist vales of the middle counties, but the berries dwindle in hot and arid situations. Manure can be advantageously and freely applied as a top-dressing in November, to remain on the surface till after the pruning in February, when it should be lightly forked into the soil without disturbing the roots.

The following are the most esteemed sorts in general cultivation: Common red, red Dutch, Knight's sweet red, champagne, common white, Dutch white, common black, and black Naples.

Mr Knight raised three or four hundred bushes from seeds in the course of his scientific experiments upon crossings, but of these very few excelled their parents. One of them, the red crystal, is superior in all respects. We have also raised currants from seeds, and have thus been instructed that seven or more years elapse ere the plants become fruitful, and therefore that propagation by cuttings is greatly preferable. Take cuttings of the young spring-wood, with a small heel of the older wood attached to it; divest it of all the buds excepting five of the uppermost and those of the heel; dibble holes six inches deep in a shady bed or border, and fix a cutting firmly in each hole, by pressure and watering. They succeed perfectly if planted in August, provided they be kept moist and entirely shaded, or in a north aspect; but the season extends thence to the beginning of March. The soil should be rich and light. Cuttings may be placed at first where they are intended to remain, or they may be transplanted after they become rooted plants, cutting away all but the upper whorl of roots: in either case, cut back to two or three buds the shoots made the first spring, and subsequently prune on every side at an outside bud, to make the bush spread at top, and render it open towards the centre.

Prune for fruit just after the buds begin to swell—never before February, or the birds will reduce the expected crop; and in pruning, shorten all the leaders and spur in the laterals, till the bushes appear like deformed masses of scrubby twigs. By these spurrings and shortenings, the bushes progress somewhat slowly, but the fruit is produced in massive clusters from the numerous spurs. The skeleton of each bush ought to consist of nine, twelve, or fifteen bearing branches, diverging at equal distances from three lower short limbs, which emerge from one main central stem; this is the best form of a neat bush, and the knife should be exercised to keep it open in the middle. If the spring-shoots push very vigorously, the first high wind generally breaks down more than half of them; but this natural pruning is frequently advantageous. The black currant requires a still more moist and cool site, and that the wood be kept young, but never pruned or spurred. Whatever shoots become black and scaly must be cut entirely out, leaving those bearing branches only which are of a delicate brown colour. The trees require frequent renewal, by taking vigorous cuttings, for old wood produces small berries. If the soil and site be congenial, and the bushes be young, the berries of the black currant are frequently as large as small black cherries.

The Gooseberry.

This universally known shrub is a native of Britain, and easily cultivated; it is indeed so hardy, and suitable for even keen climates, that remarkably little fostering is required to keep it in perfection; but it will not succeed in warm countries, its latitudinal range being in reality very limited. After a long course of culture, there are now hundreds of varieties of gooseberries; still, the kinds which keep their place in public estimation are few in number. The following are some of the leading sorts:—*Reds:* Kean's seedling, Leigh's rifleman, Boardman's British crown, red Warrington. *Whites:* Taylor's bright Venus, Wellington's glory, Saunder's Cheshire lass, Woodward's whitesmith, Cook's white eagle. *Greens:* Parkinson's laurel, large smooth green, Collier's jolly angler, Massey's heart-of-oak, Edward's jolly tar. *Yellows:* Didon's golden yellow, Prophet's regulator, Prophet's rockwood, Brotherton's golden sovereign and pilot. The following are small, but of very good flavour:—*Reds:* red champagne, red Turkey, rough red, ironmonger, and Rob Roy. *Whites:* white champagne, white crystal, early white, and white honey. *Greens:* early green hairy, green gage, and green walnut. *Yellows:* yellow champagne and rumbullion. The small red sorts ought to be preferred for preserves.

Although the gooseberry can be grown in almost any garden-soil, yet if excellence of fruit is desired, the soil must be a rich loam, not less than twelve inches deep, and resting on a well-drained, yet cool subsoil. The plantation should not be shaded too much by trees; for if these intercept the light, the fruit will not be large, full coloured, or high flavoured. Whether to form an entirely new soil, or to improve that in which the plantation is to be made, the following compost, recommended by Mr Haynes, may be advantageously adopted: Of fresh or maiden earth, from a light loamy rich pasture, take one whole spit-deep, with all the turf; to which add one-fourth of rotten stable litter, preferring that from an old hotbed made in the previous spring, which, from its softness and greater readiness to intermix with new soil, will be found preferable to every other; add one-fourth of the finest soft and black bog earth, or, in default of this, either the same quantity of the darkest-coloured leaf or vegetable earth, preferring that from hard-wooded trees. Mix the whole regularly together, laying it into one narrow heap or ridge, about a yard high, in any situation exposed to the sun and air, there to remain for six, nine, or twelve months, as

circumstances may admit; turning over the whole every three weeks, when the weather is favourable. The longer the compost remains in this state, the more advantageous it will prove.

To propagate the gooseberry, take cuttings eight inches long, of the last spring's wood, having a small piece or heel of the older wood; they are inserted about the end of October, or in spring, to the depth of three inches. The situation should be shady, the earth rather sandy, and each cutting should be fixed firmly in the soil. It is customary to remove all the buds excepting four or five at the top, which are left to form the head, produced from one central stem. Should three or four eyes break at the upper part of a cutting, it will be desirable to remove all others lower on the stem, as soon as it shall be manifest, from the vigour of growth, that there are good and sufficient roots to support them. When the head is formed, gooseberry-bushes can be spurred as directed for currants, avoiding to shorten the leading branches; or at each pruning in February, a certain quantity of the last year's wood should be retained, and a corresponding portion of the two and three years' old wood cut out; thus, as it were, renewing the trees annually. Larger berries are thus obtained from strong young wood than by the spurring-system.

When the fruit has fully set, the smaller berries may be removed for tarts, and the fine berries left to ripen for dessert. If some of the reds, as the Warrington, and the thick-skinned yellows, as the Mogul, be matted over when the fruit is ripe, it will remain good till nearly Christmas.

The Raspberry.

The raspberry is a common native plant in Britain; but has been improved by culture. The choice sorts are 1. Red Antwerp, fruit large, of high flavour, ripe in July; but by being planted behind a north wall, can be retarded, and the season thus protracted some weeks. 2. Yellow Antwerp, light coloured, very bristly wood, of luxuriant growth; fruit admirable in flavour, luscious; peculiarly adapted for dessert. 3. New double-bearing, which is rather an autumnal raspberry than strictly a double bearer, still, by due and timely pruning, a second crop is frequently obtained in autumn.

The raspberry is propagated by suckers taken up from among those which rise in abundance around strong plants. The fruitful shoots or canes bear but once, and should always be cut down in August, to admit air and light to the young shoots of the summer; and from these suckers some should be selected to renew the stock every five or six years, changing the soil or situation. Care should also be taken to remove the disorderly suckers which rise from the wandering roots. The soil for this plant should be a light loam well manured; an occasional dressing of lime-rubbish produces fine canes and very fine fruit. The plants, if placed in rows, should stand a yard or four feet asunder. They may be supported by strong stakes; confining the bearing shoots to them, the successional shoots will rise, without interfering with the others.

Raspberries are by no means of difficult culture, and are often profitably grown in shaded situations, where scarcely any other crop can be raised. Thus we have seen excellent raspberries grown in a north border, entirely secluded by walls and trees from even the faintest ray of sunshine. The waste ground around cottages is sometimes occupied with advantage by this fruit, and in such situations the raspberry bears abundantly, without the least care or culture, if not exposed to the predatory visits of village children.

The Strawberry.

The strawberry is one of the few fruits indigenous to Britain, and is found, like the bilberry and juniper, in a wild state in uncultivated spots, chiefly in woods and on tangled shrubby banks. It is likewise found in all the other northern countries of Europe, particularly in Norway, among whose rocky mountains it grows in great abundance; it prevails also in the temperate regions of South America, and abounds in the colder climate of Canada and Nova Scotia. This delicious small fruit is, in short, very generally scattered over the earth, and was the delight of ancient as well as modern times. In Latin, its name is *Fragaria*, which is supposed to be significant of its fragrance.

The strawberry is one of those plants to which nature has given the means of extensive multiplication. From the main stem there spread forth trailing suckers over the surface of the ground, and these fastening themselves by a root at every joint, as many new plants spring up as there are joints. A single tuft will, in this manner, if not kept within bounds, soon spread over a moderately sized garden.

In most parts of England strawberries are eaten alone, or dipped individually in sugar before being put into the mouth; and to suit this mode of consumption, they are brought to table with their stalks attached, which form shanks to hold by. But in Scotland they are consumed in a far more wholesale manner. There they are brought to table stripped of their stalks, and are ladled out and eaten with a plenteous infusion of cream and sugar. 'Strawberries and cream' is, in fact, one of the grand national treats which strangers may reckon upon seeing set before them in the early weeks of July, and to which generally full justice is done. In the neighbourhood of the large towns in Scotland there are many market-gardens deriving celebrity from their extensive strawberry-grounds, and to these, parties proceed from town to enjoy the fruit in perfection; that is to say, along with the richest and most delicious cream. In the vicinity of Dublin, the celebrated 'Strawberry Beds' in the same manner attract immense crowds of persons in the summer evenings, when the fruit is in its prime.

It is only in the neighbourhood of London that the successive cropping of strawberries, or the forcing of them at particular seasons, is methodically conducted on a large scale. In most parts of the country, the vicinity of Edinburgh included, the fruit in its different varieties comes almost at once into the market, the season lasting about three weeks, and then all is over. The exceeding precariousness of the crop, from the liability to damage from rains, makes the rearing of strawberries a business of uncertain profit.

After many years of observation and experience, Dr Neill recommended the following selection of sorts. Those most worthy of cultivation in small gardens are distinguished by an asterisk:

* Old Scarlet, or Virginian.	* Old Pine, or Carolina.
* Grove-end Scarlet.	Wilmot's Superb.
* Kean's Seedling.	Myatt's Pine.
* Roseberry.	* " British Queen.
Downton.	* Large Flat Hautbois.
* Knevett's.	* Prolific Hautbois.
* Elton.	Alpine, red and white (for preserving).
American Scarlet.	Wood, red and white (for preserving).
Coul Late Scarlet.	
* Princess Alice.	

The following comprehend the general directions for culture: The seasons for planting are March or September. The soil that all affect is a rich firm loam, trenched to the depth of two feet. The best and strongest-rooted runners are always to be preferred; and these should be planted at the periods above named, into beds or borders recently prepared. Many persons retain their beds or rows, during an indefinite number of years, in a tolerable state of fertility; but the triennial system appears to combine every advantage, while it avoids the two extremes of annual renewals and of protracted duration. When a bed is formed and in full bearing, it will require an annual surface-dressing of loam and manure, two parts of the former to one of the latter, early in the winter, to protect the plants and receive the new roots, which always are emitted just

below the lowest leaf-stalks. In March, the old leaves ought to be all cut off, leaving the hearts untouched; and the beds should be cleared of litter by a wooden rake. Prior to the fruit becoming ripe, the mowings of a lawn or of any soft grass or straw laid over the surface of the soil, will prevent the berries from being soiled.

Triennial System of Planting.—1. A plot or border of earth being trenched, as before directed, select, after the first rains of September, a quantity of strong and well-rooted runner-plants, and with a garden fork or trowel, set them one by one, fresh from bed, in the new ground; if in single border row, a foot apart; if in a bed, at the same distance plant from plant, but the rows two feet asunder. Fix each plant firmly, and give water over it from the rose of a watering-pot. If a set of plants be thus merely transferred without much disturbance, and watered, few will fail. Hoe the ground occasionally; and prior to or during the first frost, sprinkle some manure over and around the plants. Suffer no blossom to expand in the following spring, but leave the plants to acquire strength. Stir the ground occasionally, and cut off all runners.

2. In the second September, prepare and complete a corresponding plantation. Manure and dress the plants during winter, and those of No. 1 for the second time; and in March trim off the old leaves, and rake the surface. Let the plants of No. 1 bear their full complement, the fruit of which ought to be early, abundant, and of first-rate quality.

3. In September of the third year, repeat the work, and thus complete the plantations. Treat this and No. 2 exactly as directed for No. 1. In the following spring, suffer No. 1 to bear a second crop, No. 2 its first crop, and obliterate the blossoms of No. 3. In the September of the fourth year, dig up all the plants of No. 1, turn the ground, manure, and replant it. Thus the routine will be completed; and thus, year after year, there will be a plot progressing in one of the three stages; and if, with each approved variety, a similar routine course be adopted—and especially if a plantation be formed in the three aspects, east, south, and north, the last under a hedge or fence, to screen it from the south sun—the season of strawberries can be extended between the latter end of May and the middle of August. For the latter period, Knight's Elton is peculiarly adapted; and they who can at that time command a supply of a fruit so fine and beautiful, will have ample cause for self-congratulation.

The Cranberry.

The common cranberry (*Oxycoccus palustris*) grows wild in upland marshes and turf-bogs both in England and Scotland, and generally over the northern parts of Europe. It is a trailing-plant, with slender shrubby shoots, which are clothed with small linear leaves; the fruit is an austere red berry, about the size of the common currant. It flourishes by the sides of little mossy rills, but not among stagnant water; hence the difficulty of making it an article of culture. The American cranberry (*O. macrocarpus*) closely resembles the common species, but is a larger plant. Its fruit is also larger. Though growing wild in great abundance, it is a plant of easy culture; and in some parts of the United States, barren wastes, meadows, and coarse herbage are converted into profitable cranberry-fields at little expense. The plant grows well on sandy bogs; and if these are covered with brushwood, the bushes should be cleared away. Some cultivators plough the land previous to planting; the latter process being performed by digging holes, four feet distant each way, to receive the roots of the young plants. In three years, the whole ground is covered, and an acre in full bearing will often produce 200 bushels, which bring about one dollar per bushel.

The cultivation of the American cranberry in our own country was first recommended by Sir Joseph Banks; and several gardeners have been so successful in the attempt, that this berry may now be regarded as one of our cultivated fruits. 'Wherever there is a pond,' says Neill, 'the margin may, at a trifling expense, be fitted for the culture of this plant, and it will continue productive for many years. All that is necessary is, to drive in a few stakes, two or three feet from the margin of the pond, and to place some old boards within these, so as to prevent the soil of the cranberry-bed from falling into the water; then to lay a parcel of small stones or rubbish into the bottom, and over it peat or bog-earth, to the depth of about three inches above, and seven inches below, the usual surface of the water. In such a situation, the plants grow readily; and if a few be put in, they entirely cover the bed in a year or two, by means of their long runners, which take root at different points. From a very small space, a very large quantity of cranberries may be gathered; and they prove a remarkably regular crop, scarcely affected by the state of the weather, and not subject to the attacks of insects.' Although a moist situation is best suited to the plant, yet, with a due mixture of bog-earth, it will flourish, producing abundant crops, even in a comparatively dry soil.

The Grape Vine.

The vine (*Vitis vinifera*), from the juice of whose fruit wine is made by a process of fermentation, is a plant of Eastern origin, which, in the course of ages, has been introduced into all the countries of Southern and Central Europe. Requiring a fine climate, it will not bear fruit in the open air in most parts of Britain; and it is only in fine seasons, and in good exposures, that its fruit is worth eating, even in the southern parts; in general, the grapes grown in gardens about London are small, and not presentable at table. In the north of France and Germany, they are little better, and we do not really get fine grapes of a proper size till we reach Italy or Portugal. In England, however, grapes produced in hothouses surpass in size and flavour the fruit of the Portugal vines.

Throughout the continent, the practice is to grow vines in large fields, either on plains or the sides of hills, which are fully exposed to the sun. They are trained in rows, tied to stakes, and are pruned to a height of about four or five feet; on the Rhine, they seldom exceed three or four feet; and at a distance, the ground has somewhat the appearance of being covered with staked beans or peas. In Italy, the vines are trained to a greater height, and are made to cling to horizontal palings, as if from the roof of a hothouse.

To those in the southern parts of England, who desire to rear the vine in gardens and on walls, we offer the following directions: The varieties most suitable for culture are—1. The white sweet-water, with round berries, somewhat tinged with yellow, and faintly streaked with red on the sunny side. 2. The white muscadine; bunches rather loose, berries not very large, yellowish, and abounding with saccharine juice. 3. The small black cluster, with berries between red and purple, closely packed, very sweet, and luscious in flavour. 4. Turner's hardy, a fruitful tree, and very certain bearer; berries of medium size, varying from dark-red to deepish purple.

A sound turfy loam, to the depth of eighteen inches, rendered open by small fragments of old lime-rubbish and a portion of crushed bones, will support any vine, and promote its fertility; and these materials can be introduced by degrees, first near the roots, then at a greater distance, to replace a corresponding quantity of old soil; thus little expense will be incurred, and still less labour. But if a new border be contemplated, and outlay be not considered, it will of course be best to complete the work in the first instance.

Vines are propagated by single eyes, by cuttings, and

by layers, placed in pots when it is intended to remove the plants to borders or vineries. The soil should be a light, rich, sandy earth, or perfectly decayed manure and sand in equal parts; but they who wish to raise vines without loss of time, should plant cuttings taken from vines of known fertility, and of the yearling shoots which are themselves actually fruitful. Each should have three bold eyes on the young wood, and each should retain at its base a small piece of the previous year's wood. The season for planting is the month of March, and the method very simple. Dibble a hole from four to six inches in front of the wall or fence, deep enough to receive the entire cutting. Mix together equal parts of black leaf-mould and white sand; put in the hole enough of this to raise the bottom one inch, and ram it hard with a blunt stick; then insert the cutting, and hold it firm in the centre of the hole, while that is filled brimful with the compost, which is brought into still closer contact with the shoot by watering. Make the ground quite even, and its surface level with the uppermost bud, then cover the cutting with a small hand-glass. If the ground is kept moderately moist, not two cuttings in a dozen will fail. If more than one shoot break, and attain the height of five or six inches, the stronger only should be retained, slipping the other off below ground. This shoot must grow till its point become spindling, when it should be nipped back; and all future growth should be thus stopped above its lowest leaf, as also the laterals that appear during the growth of the main shoot. Great care must be taken to keep the vine regularly nailed and secured by soft and roomy ties, to prevent accident, and the danger of being snapped by the wind.

As the aspects suitable to the vine are confined between south-east and south-west, the cuttings, if not duly supplied with water, may be droughted and perish before they become completely furnished with roots; but when once established, the main shoot will grow rapidly, perhaps attaining the height of a common fence, and ripen their wood early. In the end of September, let each be cut down to an inch above the three lowest buds; mulch the ground around the stems and over the roots as winter approaches, and watch the spring progress of the eyes. If possible, obtain and secure two equal shoots; and if the wall or fence be from eight to ten feet high or more, lead these shoots horizontally right and left about six inches above the soil, and secure them by shreds and nails. If the wall be six feet or under, retain but one strong shoot, and train it perpendicularly. In September, cut back according to the strength: thus, if the wood of the single rod last mentioned measure from one-third to half an inch in thickness, and the eyes be full, and from four to six inches apart, cut the shoot at the top of the fence, removing also the remains of all laterals and tendrils. The two horizontals will perhaps be rather slighter, yet if they be fully ripe, and furnished with bold eyes, they may be left three or four feet long on each side of the short main stem, but all the buds on the under side of each must be cut away; mulch the ground as before, and in March following, carefully fork in the manure.

Bearing Condition of the Vine.—The fourth spring will find the vines in a fruitful state; but, previously, the trees prepared for a dwarf-fence should be so pruned as to retain but three horizontal branches on each side of the main stems, about eighteen inches asunder, the intermediate branches being cut back to their lowest bold eye beyond the stem. This eye is designed to produce a new shoot, to take the place of the bearing-shoot, which, after the fruit is taken, must be cut away. Thus the vine will henceforward produce, year by year, two systems of branches, one of which will comprise year-old bearing wood, the other a corresponding series of green wood, which will produce the fruit of the following year. This description would almost suffice to elucidate the habits of the vine; yet to leave no doubt on a subject which involves the entire theory of pruning, it will be understood that this tree bears its fruit solely upon the green shoots of the present year, which spring from the eyes of the pale-brown wood of the previous year. When, therefore, a vine is of age, and has acquired sufficient strength to support a crop of fruit, it will generally be wise to provide a new series of bearing-wood every year, because the fruit of new wood—in the white varieties particularly—is always superior. In this horizontal alternate system for low fences, each new branch may safely be permitted to extend itself at least two joints beyond its predecessor, always remembering to cut back, early in the autumn, to a short distance above a bold eye seated on perfectly ripe wood; for thus the tree will acquire strength and extent at the same time; and experience proves that, in ordinary circumstances, the fertility of a tree should be moderated, and kept below the supporting power.

The trees on the second system of training for high walls must be pruned in a similar manner, and upon corresponding principles. In the autumn of the third year, three out of four branches will be cut down to the lowest bold eye, and a few vertical shoots, from thirty inches to a yard apart, will remain; and these also must be pruned to a strong eye situated on mature wood. This system will furnish new bearing-wood every year, increasing in length as the power of the tree augments; while also the low horizontal stems will extend gradually in due proportion. At first, one, or at most two bunches, must be permitted to remain upon each upright branch. In the fifth season, a greater crop may be taken, always, however, remembering to restrict the fertility of the vine; for by so doing, its vegetating power will keep in the advance, till, in the end, the entire fence will be filled with vigorous branches, annually renewed, from which a very heavy crop may be gathered without tasking the vine in any degree that shall produce debility.

The spur-system of pruning back the bearing-shoot annually, may occasionally be adopted with black grapes, and not without advantage; yet the system of yearly renewal leaves the vine at the entire command of the pruner, and procures large clusters of fruit. The few remarks above offered enter little into minutiæ, but they elucidate general principles; and if applied practically, will, we believe, lead to improvement in grape-growing.

The fruit of the vine grows in clusters or bunches, as many, perhaps, as a hundred grapes in the bunch. It is not desirable that so many should cluster together, for when numerous, they are apt to be very small, and to be so compact in the mass, that those within do not ripen. Bunches with many grapes, therefore, should be thinned, by clipping out those of the smallest size, which will allow the others to grow to the proper dimensions. In very many instances, grapes grown on walls in gardens are spoiled by vermin, the interstices in the bunches being often filled with spiders' webs and insects of different kinds. All this is a result of carelessness in not keeping the walls clean, and thinning and otherwise attending to the bunches. As a preventive, let the walls in winter be lime-washed, including all branches of the vines, and take some pains to remove all vermin which appear in the fruit-season.

Forcing.—Of the growing of vines in hothouses or vineries, it is not our intention to speak; but for the class of persons whom we address, the following suggestive account of a method for forcing vines in humble edifices, given by Mr M'Intosh, in the *Orchard*, seems so suitable, that we take leave to offer it: 'In many parts of the continent, and even in some few instances in this country, vines are forced in very humble edifices. The Dutch, Flemings, and Germans use pits, often not exceeding three or four feet in depth. These are

sometimes heated by dung or tan being placed within them, which give out a mild, humid heat, serviceable to the vine while the buds are breaking; and this, with the proper husbanding of the solar heat by judicious ventilation, is often found sufficient to produce ripe grapes at an early period. Other instances occur of such pits being heated by a smoke-flue, to which very moderate fires are applied. But what is most novel in these pits is, the vines being planted outside—the wood that is to produce the fruit is trained under the glass within, while the young wood for succeeding crops is allowed to grow without, where, under a brighter sunshine than we enjoy, the wood becomes perfectly ripened; and when the crop is gathered, the old wood, or that which produced fruit this year, is entirely cut out, and replaced with the young wood hitherto growing without the pit. Vines are also ripened on the continent by having glass frames placed against the wall on which they grow, about the time the fruit is half or three parts swelled, at which period those glasses are not in use which have been employed in forcing early crops of melons, salads, &c. The solar heat collected by this contrivance ripens the fruit well, and fully matures the wood for the following season.'

Vine Diseases—Grape Blight.—The cultivation of vines under glass, although in the present day exhibiting highly successful results, has all along been attended with certain disadvantages, arising chiefly from the unnatural conditions to which the plants are necessarily subjected. Much has been written on vine-borders and on systems of pruning, and our horticultural literature is literally loaded with explanations of the causes of *shanking* and other failures of the grape-vine. Of late years, a new disease, known as the grape-blight, or vine-mildew, has made its appearance, and has proved very destructive to the crop. Unfortunately, this new disease is not confined to the hothouse, but becomes even more troublesome where grapes are grown in the open air. It has, in fact, become as great a scourge of the wine-countries as the potato disease has been to Ireland; and has served in many cases to change the course of industry, as, for example, at Teneriffe, where, according to Professor Piazzi Smyth, the vine is being displaced by the cochineal insect, which gives a more certain return. The grape-blight first manifested itself at Margate, in England, and gradually spread into France, appearing at Versailles in 1848, at Paris in 1849, and finally extending to the south of France in 1851; at the same time, it rapidly travelled the whole length of Italy, from the coast of Liguria to Naples; then, as autumn approached, taking a retrograde course through the Tyrol, as far as Botzen, overrunning nearly the whole of Switzerland northward to Winterthur, and at last trespassing on certain isolated points of Germany at the Hardgebirge, in Baden at Salem, and in Würtemberg at Stuttgart and Cannstadt (Hugo von Mohl). The disease seems in many cases to have made its first appearance on vines under glass, those in the open air becoming subsequently affected. According to Mohl, where vines are grown exclusively in the open air, those trained to walls suffer more than the vineyards in the open field. In many cases, the disease has been observed to pass from the trellises to the neighbouring vineyards. 'It reached the greatest height on those trellises which stand under the wide-spreading roofs of the Swiss houses.' Invariably the finest vines suffer most severely, and especially those that are carefully pruned and trained under shelter.

The diseased condition is accompanied by, and is apparently due to a minute fungus (*Oidium Tuckeri*), which consists of delicate cobweb-like threads, which spread over the surface of the young shoots, leaves, and fruit of the vine, decomposing its juices, and interrupting development of the tissues. The effect of the parasitic mould upon the fruit is most remarkable: the filaments referred to spread over the whole surface of the fruit, acting detrimentally upon its skin only; the soft fleshy interior goes on expanding in vigorous growth; but the infected skin, having lost its vigour, ceases to expand in proportion, so that the berry becomes ruptured, and either dries up or rots. In infected districts, whole bunches may be seen in this condition—the vine-twigs languishing, and left by the disheartened cultivator to be choked with weeds. We have had the opportunity of studying the disease in England; but have sought in vain for diseased vines in Scotland. It is not necessary that we should here consider whether the *Oidium Tuckeri* is a new and specifically distinct fungus, or merely an aberrant form of another known species. That question must still be regarded as quite an open one, especially since the experiments of Mr Lowe, detailed in a paper read to the Botanical Society on the 11th of June 1857, have shewn so many so-called species to be referrible to the *Aspergillus glaucus*, or common blue mould.

There is no *effectual* remedy applicable to extensive vineyards in the open air; but dusting with sulphur proves highly beneficial where the plantation is sufficiently small to permit of its being well done. In hot-houses, this remedy is of the greatest service, and ought to be resorted to in all cases where the disease makes its appearance.

The Fig.

The fig-tree is a delicate exotic like the grape-vine, and great care is required to bring crops of the fruit to maturity in the open air. There are many kinds of the fig-tree, but the greater number are adapted to culture under glass only.

In this country, the nomenclature of figs is very unsatisfactory; but the following list embraces most of those known in cultivation. The kinds best adapted for forcing are marked with an asterisk, the others being suitable for the open wall in warm sheltered situations. The fruit cannot, however, be depended upon except in favourable seasons:

* Black Ischia.	Pregussata.
Brown Ischia.	Lee's Perpetual.
Black Genoa.	* Early white.
Brunswick or Madonna.	* Marseilles or Figue blanche.
* Brown Turkey.	

The best soil for fig-trees is a light fresh loam; but the chief essential to promote fertility is a hard and dry bottom of chalk, gravel, or artificial pavement; a dry substratum, and little depth of soil—that is, from one foot to eighteen inches—are therefore what the gardener must provide, if he expects to render the trees permanently fruitful.

As to culture and training, both are extremely simple. Rogers says, and very justly, 'that the knife is seldom wanted' [that is, in shortening; though, from the extreme luxuriance of the wood, it is frequently necessary to cut out many entire shoots]; 'pinching off the points of the young shoots during the months of May and June with the thumb and finger is the most effectual pruning.' Mr Knight restricted himself to compressing the points of the green shoots till the substance was felt to yield under the finger and thumb, by which pressure a check is given to luxuriance.

To secure fruit in due season, the pruner must recollect that in Italy and the south of Europe two crops of figs are produced yearly. Those large figs which are seen on fruitful trees here late in summer, are developed in spring, and would ripen early in a warm climate; but our winters check their progress, and generally destroy them. The crop which ripens in August is developed late in the preceding summer, and is extremely minute, almost invisible, in September; these figs are situated near the terminations of those green shoots which have been pinched or compressed; therefore the large green figs should be displaced by

mid-August, and then it will frequently be seen that two minute fruits form in lieu of the one; and these, if the tree be protected, will ripen at the season mentioned. As to protection, it will be proper to unnail and bend down the upper shoots, so as to bring them into moderate compass, then to pass a few straw-bands among and across them, and finally to cover the whole with a mat or canvas sheet.

In April, train in, straight and regularly, all the bearing-wood; and as the trees grow, suffer the breast-wood to curve forward at its pleasure, pinching the points as directed. Not one shoot is to be cut shorter; but if the wood become redundant, branches which obscure the fruit should be removed, reserving those which will manifestly be fertile, and which can be duly trained in the following spring.

The Filbert.

The filbert is an improved variety of the common hazel-nut. Both plants are monœcious; that is, they produce male and fruitful blossoms very early in the year on the same tree, but separate from each other. As the trees are pruned—spurred, as it is termed—in autumn, care must be taken to reserve a number of catkins. The following are the methods of culture: Strong suckers, taken in autumn, are either planted in the nursery, or at once in the places where they are to remain; and these grow three or four years, and are then cut down within a few inches of the ground. From the stems, several strong shoots are produced, which, in the second year after cutting down, are generally shortened by one-third of their length. Regular figure and an open head are procured by training the branches. In the third year, as the bush approaches maturity, short shoots (spurs) spring from the eyes, and are suffered to grow till the autumn, when they are cut back nearly to their origin, whilst also the leading shoots of the previous year are shortened two-thirds.

In the following spring, several small shoots arise from the base of the small branches which were cut off the preceding autumn, in consequence of the curtailment of the leading trained branches, and upon these secondary spurs the fruit may be expected; these shoots augment in number yearly, insomuch that many must be cast away. The largest are removed; the lesser remain, being more fertile in their habit. Many decay yearly; but whether they do so or not, those which have borne filberts are always cut away, and a fresh succession provided as future bearers. The leading shoot is every year shortened two-thirds or more, if the tree be weak, and the whole height of the branches must not exceed six feet. In order to strengthen the tree as much as possible, the suckers of the roots are eradicated.

The crops thus produced are sometimes enormous, followed, however, by intervals of barrenness. We have not heretofore adopted the method of pruning, leaving the trees more to the order of nature; but it is right to try experiments; and when a row of young trees exists, a comparison might readily be obtained, by pruning alternate trees, or one of every three trees, by the 'spur-system;' always, however, observing to keep the head of every tree open, and to cut away its upright central leader.

The Mulberry.

The mulberry is a native of Italy, introduced in 1548. The structure of its flowers and fruit is very singular; like the nut and filbert, the males are distinct from the females; the latter do not always expand at the same time as the males, and therefore are not fertilised. The black mulberry thrives best in good loam; the bed ought to be deep, and to rest on a dry sandy subsoil. The fruit sometimes fails; and on this subject Rogers observes, that fertility may depend very much on the warmth of the weather at the time of blossoming, and on the circumstance of both male and female flowers coming forth at the same time; sometimes also the male catkins drop before the fruit-blossoms expand. Williams of Pitmaston suggests, 'that no tree receives more benefit from the spade and dunghill than the mulberry; it ought therefore to be frequently dug about the roots, and occasionally assisted with manure.' Others consider a velvety piece of turf as the best site. When the buds expand in the third spring, it is desirable to obtain four shoots on each side of the upright stem, and all the shoots that will break from the two horizontals, which latter are to be led upright, and secured as they advance.

The Melon.

The melon requires more care in cultivation than most amateur gardeners can bestow upon it; but of late years the introduction of heating by hot water for forcing purposes has largely displaced the old system of dung-heaps, and has simplified the management of melons, and rendered them a more certain crop. They are now usually grown in low, glazed pits, having pipes of hot water flowing beneath the bed of soil, to afford bottom-heat. The most recent system of culture is that given in the *Florist and Fruitist* for June 1857, from which some of the following hints are abridged: The trellis for training the melon-shoots should be eighteen inches from the glass, and the foliage should be kept six or seven inches from the glass, so as to permit a free circulation of air. The first sowing may be made at the end of November, the seeds being sown thinly in pans; the seedlings require great attention at this dull season; keep them near the light, and when they are sufficiently strong, prick them singly into pots, using pure loam. Early in January, prepare for planting. Melons succeed best in marly or clayey loam, and the soil must be made firm before planting, whether the plants are grown in the beds or in pots; the latter are preferred for the earliest crop. In the middle of January, the soil in the pots having become warm, the seedlings are to be planted, one in each pot. When the stem elongates, carefully tie each to a stick reaching from the pot to the trellis, and when trained along the trellis, stop them, by pinching out the point of the shoot, to induce fertility. Three fruits will be plenty to allow to swell off on each plant. Be careful to regulate the temperature, and to keep the atmosphere moist, watering the soil occasionally with liquid manure. The following are some of the best varieties in cultivation at the present time (1857): Bromhall, Victory of Bath, Egyptian Green-flesh, Orion, Beechwood, Trentham Hybrid.

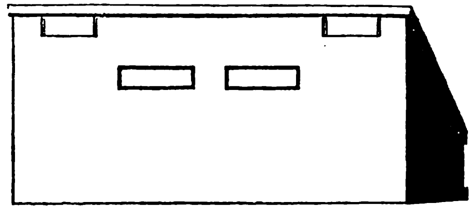
THE ORCHARD-HOUSE.

Of late years, an innovation has been made on gardening practices and prejudices, by the introduction of hardy fruit-trees to pot-culture. This may at first sight seem a refinement in horticultural art, which is not needed by those whom it is the chief object of these pages to instruct; but on closer examination, it will be found that the orchard-house, or, as its author, Mr Rivers, prefers to call it, the 'glass-roofed shed,' does not so much belong to the professional gardener as to the amateur and the cottager, and especially to the tenant of a town-garden. It is described as a place requiring but little expense to erect, but little experience and attention to manage, and yet giving pleasing results to the suburban gardener, who has but a small garden—which must be a *multum in parvo*—to the amateur with plenty of gardening taste, and but a limited income; in short, to a numerous class, with minds full of refinement and capabilities of enjoyment of horticultural pleasures, but with purses not so bountifully supplied.

The principal object of these orchard-houses is to grow small apple and pear trees, cherries, &c., in pots, to greater perfection than can be done in the open

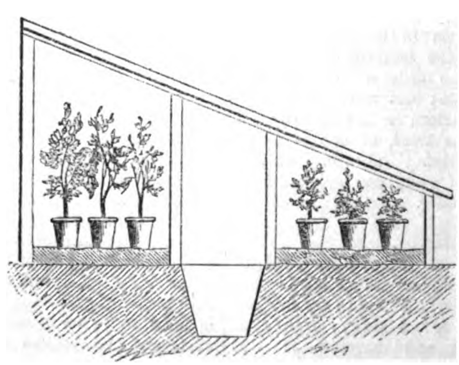
ground, as well as to obtain grapes, &c., without the expense of vineries. By the peculiar management adopted by Mr Rivers, which shall be explained, a crop of fruit may be realised in course of a year or two after planting, and this is a great point, inasmuch as it enables the amateur to reap a speedy harvest; for it has long been a standing adage in gardening, that 'those who plant pears plant for their heirs.'

Mr Rivers thus describes his 'glass-roofed sheds:' Their length may be from ten feet to one hundred or more, according to means and space; but their breadth and height must be according to the following dimensions: Suppose the structure is to be thirty feet long; a ground-plan, thirty feet long and twelve wide, must be marked out; then ten posts or studs of oak or good yellow deal, four inches by three, and nine feet in length, must be fixed two feet in the ground firmly, the ground-ends being previously charred to the extent of two feet four inches from the bottom: this back-line of studs will thus stand seven feet in height clear from the surface. For the front-wall, ten studs four feet long must be inserted 1½ feet in the ground, so that they stand two feet six inches clear from the surface: on these studs, both at front and back, must be nailed a plate four inches by 2½ inches, on which the rafters are to rest: the studs are thus far arranged into two lines. The rafters are fourteen feet long, and four by two inches in thickness, placed with the narrow surface upwards. To spare the trouble of 'ploughing,' to make the rebate for the glass, which is great labour and waste of material, a slip of ½-inch board, ⅞ths of an inch wide, is nailed on the upper side of each rafter exactly in the centre; this will leave ⅝ths of an inch on each side for the glass to rest on—not too much for glass twenty inches wide. The rafters are now fitted on the plates at top and bottom; they must never be mortised, but let in at top by cutting out a piece, and sloped off at bottom. To receive the glass at the top of the rafters, a piece of ¾-inch deal-board, six inches wide, must be nailed along the top to the end of each rafter, so as to be even with the surface, and in this should be a groove to receive the upper end of each piece of glass; at the bottom, a piece of board, one inch thick and six inches wide, must be let in for the glass to rest on, and to carry off the water. We have thus a sloping roof seven feet three inches high at back, and two feet nine inches in front. The glass used is 16-oz. British sheet, costing about 2½d. to 3d. per foot, and the best size of pane is twenty by twelve inches, the panes being placed crosswise, so that the rafters must be about twenty inches asunder. On and outside the back-studs, ½-inch boards must be nailed, well-seasoned, so that they do not shrink too much, and painted white or stone colour. In the back-wall, sliding shutters, 2½ feet by one foot, in grooves, must be formed for complete ventilation—two close to the roof, and two about eighteen inches from it, as in the annexed sketch.



Back of Orchard-house.

The front has also ½-inch boards nailed on outside the studs; one of them—the upper one—to be on hinges, so as to let down; and thus air is given throughout the whole length of the house. The *building* is now completed; but its low dimensions do not admit the builder. It is therefore necessary to form a footpath by making a trench 2½ feet wide and two feet deep in the centre of the ground-plan, which will leave a raised border on either side, four feet nine inches wide; the sides of the border may be supported by boards or brickwork. The border is to be made loose and open by a mixture of cinders, lime-rubbish, broken bricks, &c., and is enriched by manure. The pots containing the tiny fruit-trees are placed on the surface of the borders, and the foliage is thus near the glass. The roots make their way through the apertures in the bottom of the pots, which are enlarged for that purpose, and the plants thus, even in small pots, attain enough of vigour to support a crop of fruit. After the fruit is gathered, the pots are raised slightly on one side, and the protruding roots cut off with a knife; and the plants soon go to rest for the winter. It will be seen that the principle is to permit the plant to feed in the rich border by means of its protruded roots while the fruit is being matured, while any tendency to luxuriance is checked by the removal of these roots in autumn. The trees are thus kept of convenient size and in a very healthy bearing condition. Trees adapted for this method are kept for sale in pots in all the larger nurseries; and for ample details of cultivating the different sorts, we would refer to Mr Rivers's pamphlet. This system renders the fruit-trees portable; and such trees now occasionally appear at horticultural exhibitions, while they also present a novel feature in the dessert. 'What can be more gratifying than bushes of Moor-park or peach apricots, studded with their golden fruit, arranged on the sideboard of the dining-room, or the same of peaches, nectarines, plums, cherries, and grapes?'



Section of Orchard House.

A Pine Forest.

ARBORICULTURE.

CULTIVATION is so intimately associated in our minds with an annual, or more frequent stirring of the soil, that the term ARBORICULTURE—the cultivation of forest-trees—would at first sight almost seem to imply a paradox. We are so accustomed to see trees growing in extensive forests, on the bleak hillsides and in rocky valleys, whose soil and climate are incapable of supporting the ordinary races of cultivated plants, that we are prone to adopt the notion that trees grow out of the old turf of their own accord, and can be none the better of any care or attention on the part of man. Various writers have from time to time endeavoured to contradict this popular fallacy, and to shew that forest-trees require as much care and attention as any other cultivated crop. Such views have not as yet, however, been universally adopted by landed proprietors and others whose interests are concerned; but there can be no question that they are daily gaining ground, and will erelong effect important changes in the arboriculture of the British Islands. The rapid advances which have been made in the two sister-branches of rural economy, Agriculture and Horticulture, within the present century, hold out hopes that Arboriculture, which has now begun to follow their footsteps, will soon present an aspect very different from that which it has so long exhibited as a mere empirical art. Geology, Vegetable Physiology, Botany, and Entomology, all have important bearings on Arboriculture, and upon these it ought to be founded. It is a branch of industry upon which our national prosperity very much depends; and happily much improvement has of late years been effected in the management of our royal forests, which, if Blue Books speak truly, have met with an amount of neglect which contrasts strongly with the importance of our naval force. This is not to be wondered at, seeing that private properties of the same kind have in many instances been allowed to grow on and decay, without attention or control, until a pressure of debt on the proprietor, or some other untoward event, has led to an investigation of all available sources of income; and then, in most cases, a total clearing of the forests has taken place for the sake of their marketable timber, without any consideration as to the possibility of an increase of ultimate revenue from partial thinning or other steps of judicious management.

Mr James Brown, in the *Transactions of the Scottish Arboricultural Society*, says: 'Arboriculture is a much more difficult subject to deal with than either farming or gardening, inasmuch as a greater length of time is necessary to develop improvements and conduct them to a profitable issue. Hence the reason that the cultivation of trees on sound principles has hitherto been so very much neglected, and consequently that their culture as a crop has generally been attended with unsatisfactory pecuniary results. Instances, however, are by no means wanting in which this branch of rural economy has been conducted on sound principles, and in all such it is invariably found to be highly productive of profit to the proprietors, both directly by the proceeds of its produce, and indirectly by the shelter produced, and the consequent enhancing of the value of arable land. Such examples freely justify the expectation that, were all plantations cultivated on like principles according to their kind, pretty nearly the same results would in all cases follow. But although many instances of well-managed plantations could be indicated, and of such

results naturally occurring, still I believe that every intelligent forester will agree with me that this happy condition of things in respect to arboriculture is of comparatively limited extent, and that at least two-thirds of the plantations in Great Britain are at the present time either almost entirely neglected, or so dealt with that their condition is hopeless, whether as a profitable or an ornamental crop. This assertion may to some appear overstrained and beyond the truth, but it is based upon my own experience in surveying woods in all parts of the country during the last ten years. In England, I have seen oak-plantations of nearly thirty years' standing, with the trees in them only from four to five feet apart. From never having received the slightest attention as to thinning, the crop, as might have been expected, consisted of mere poles. This is an average illustration of the degree of knowledge exercised with regard to the rearing of timber in many parts of England, and it is scarcely to be wondered that profitable results do not follow such management. In Scotland, too, I have found a considerable extent of plantations which had never been thinned, although nearly thirty-five years of age. In these I found the trees averaging only about four feet apart; and of course, in such a condition of crowdedness, they were so slender that to attempt thinning or improving them was hopeless. Such examples are sufficient to shew that there is very great room for improvement in arboriculture both in England and Scotland.'

STRUCTURE AND PHYSIOLOGY OF TREES.

The general structure and physiology of plants have been explained under VEGETABLE PHYSIOLOGY and SYSTEMATIC BOTANY, to which reference may be made. The *stem*, which chiefly concerns our present subject, presents an infinite variety of modifications—assuming the form of a globular or columnar mass, as in cacti; or a pseudo-bulb, as in orchids; a hollow-jointed culm, as in grasses; a lofty branchless caudex, as in palms; or it may be twisted in a spiral manner around other plants, or form an underground rhizome, or an upright branching woody trunk, such as we see in our ordinary forest-trees. But all modifications of the stem are reducible to three well-marked forms, which differ not only in their mode of growth, but also sufficiently so in outward appearance as to render them easy of recognition. The three forms of stem are these:

1. *The Exogenous*, or *Outward-growing Stem*, which, in its growth, increases indefinitely in an outward direction by the annual formation of new layers of woody matter formed on the outside of the preceding layers, but inside the bark. This kind of stem is therefore an 'outward grower,' its thickness being yearly increased by the addition of successive concentric layers of wood.

2. *The Endogenous*, or *Inward-growing Stem*, whose increase takes place by the formation of new tissues towards the centre, so that the stem increases in thickness by the newly formed woody matter pushing out that previously formed, and not by the addition of new layers to the circumference.

3. *The Acrogenous Stem*, in which the increase takes place at the summit only, by the union of the bases of the leaves. It is, therefore, a summit-grower.

These three modifications of stems accord with other important structural peculiarities. All plants having *exogenous* stems have also an embryo with two cotyledons, or seed-leaves, and their proper leaves have usually a reticulated or netted venation; all those having *endogenous* stems have an embryo with one cotyledon, and their leaves usually have parallel venation; and all *acrogenous* plants have no proper seed containing an embryo, being propagated by unicellular bodies called spores.

All these three classes include a certain number of *woody* stems—that is, stems whose tissue is sufficiently dense to form timber; but that of acrogenous stems (tree-ferns, &c.) is not profitably available for this purpose. Our timber-trees are therefore, in practice, reduced to the first and second classes. But we further find that endogenous stems, in their woody form (palms, &c.), are confined to warm regions of the globe, so that these also do not concern the British forester. On the other hand, woody exogenous stems are common in all northern countries, and to this class belong all our timber-trees in the British Islands.

In common language, the trunk is often named the *bole*; and it is this part which affords the timber for which most trees are reared. The trunk, and also the branches, are covered with *bark*, consisting of a series of thin layers; while on the outside of all is a very thin layer of a different substance, called the *epidermis*, or cuticle. The inner layer of bark receives the name of *liber*; it was on this substance that the ancients, before the invention of printing, were accustomed to write; and *liber*, it is well known, is the Latin word for a book. Within the bark is the wood, consisting chiefly of wood-cells or tubes and vascular tissues, closely interlaced. In the centre of the trunk is a small space filled with a soft substance called *pith*, from which proceed the medullary rays.

The growth of a true exogenous bole is as follows: The stem of a seedling consists at first only of cellular tissue, surrounded by an epidermis; but as soon as the leaves have expanded, some bundles of woody fibre are deposited, so as to have the appearance, in cross-section, of a dotted circle just within the skin. As the tree advances in growth, the cellular tissue in the centre becomes the pith, and rays of cells, forming the medullary rays, extend to the epidermis between the bundles of woody fibre. A membrane, or rather layer of vascular tissue, then forms round the pith or *medulla*, so as to separate it from the bundles of woody fibre, and the pith, in some cases, takes the form of a star with rays diverging from a centre. In the second year of a tree's life, the rays and the central pith both contract as fresh layers of woody fibre are deposited, and they continue to do so every year till the tree is full grown. This process of growth of the stem by concentric layers of woody matter is continued every year, and as the vascular tissue has always a different appearance from the tissue of the wood, the rings of vessels between the layers of wood, which are called *concentric circles*, and the medullary rays diminished to fine lines, may be always traced in a section of the trunk of a tree. The medullary rays become changed in time into thin hard plates, which still radiate from the centre to the outer circumference of the tree, and form what is called by carpenters the *silver grain* of wood. The central pith, in the meantime, has diminished to a mere speck in the middle of the tree. The newly deposited layer of wood appears soft and white for the first year, and is called the *sap-wood*. The inner layers form what is called the *heart-wood* or *duramen*, which is extremely hard and durable. As the layers of wood are thus distinct, and as one is generally deposited in temperate climates every year, it has been supposed that the age of a tree might be found by counting the number of concentric circles; but this rule does not always hold good, for the reasons hereafter explained. The sap-wood of regularly formed wood is usually white; but the heart-wood in many cases changes its colour to brown of various shades, dark red, or even black, according to the character of the tree. The *branches* precisely resemble the trunk in every feature of structure.

It will thus be seen that the trunk of a tree—of the exogenous kind—consists of a number of cylinders enclosing one another like so many layers or concentric circles disposed around an axis; and that, as a circular layer is deposited every year, it is possible to some extent to ascertain the age of the tree by counting the number of the layers. Decandolle observes that this method of reckoning is not liable to much error, but the inspection must be conducted with the greatest care, for

the older circles become condensed into a mass, and their number can only be guessed at by measurement. His plan is as follows: 'When I have got a section of an old tree, on which I can see the circles, I place a sheet of paper upon it, extending from the centre to the circumference. On this paper I mark every circle, shewing also the situation of the pith, the bark, the name of the tree, the country where it grew, and any other necessary observations. I also mark in a stronger manner the lines which indicate every *ten years*, and thus I measure their growth at *ten years'* intervals. Measuring from centre to circumference gives me the circles; doubling this, I have the diameter; and multiplying by six, I have the circumference.' He then presents a table of the periods of increase in the diameter of various trees, an inspection of which proves that every tree, after having grown rapidly when young, seems at a certain age to take a regular march of growth, and also that as trees advance in age, they still continue to form layers as thick as they previously did subsequently to the period of rapid growth. If such tables were multiplied to a sufficient extent, they would form data from which, by ascertaining the circumference of a tree, its age might be known without having recourse to the destructive process of cutting deep into the growing timber. 'If,' says our author, 'one cannot get a transverse section of a trunk, then one must seek for old specimens of each kind, the date of whose planting is known, measure their circumference, deduce their average growth, and calculate from them the age of other trees of the same kind, always keeping in mind that young trees grow faster than old ones.' Decandolle cites numerous instances of trees whose ages have been ascertained according to the rule here laid down. Some of these appear to be many centuries, if not thousands of years old; and what is remarkable, still exhibit symptoms of verdure and vitality. Such calculations are apt, however, to lead to very erroneous results when applied to trees grown in warm climates; and even in Europe the greatest caution is required.

The fact that trees of such vast age continue to bear foliage and fruit, affords indubitable proof of a very remarkable circumstance connected with the vegetable kingdom. In man and all other animals, we find an organisation, and a process of life going on, which are destined to cease at a certain period. But it is otherwise with trees. They appear to possess the power of growing on for ever without exhibiting any symptoms of decay, unless from accidental or extraneous causes. 'As there is formed every year a ligneous deposit, and generally new organs, there is not among the vegetable creation place for that hardness or rigidity, that obstruction of old and permanent organs, which constitute properly the *death from age*, and, consequently, that being the case, trees can only die from accidental causes. Trees do not die from age, in the true sense of the word: they have no fixed period of existence; and, consequently, some may be found that have arrived at an extraordinary age.' But although a tree thus possesses in itself the elements of continual strength and youth, numerous causes step in to interrupt or destroy its existence; so that we are not to be surprised if the number of such vegetable patriarchs should prove exceedingly small, compared with the immense extent of the earth's surface which is covered with forest-growth.

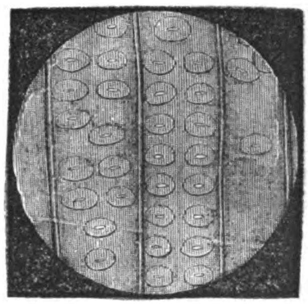
CLASSIFICATION OF TREES.

In arboriculture, trees are sometimes classified according to their uses; for example—1. Trees which produce straight timber for masts and long planks—as the various tribes of pines. 2. Trees which afford crooked timber for knees or bends in the ribs of ships, &c.—as the oak, sweet chestnut, broad-leaved elm, &c. 3. Trees which give tough pieces of timber—as the yew, holly, thorn, ash, hickory, maple, laburnum, &c. 4. Hard-wood trees—as the oak, beech, plane, walnut, box, and holly. 5. Soft-wood trees—as the poplar, large willow, lime, horse-chestnut, &c. 6. Wood or spray grown for hoops, baskets, besoms, poles, &c.—as the dwarf willows and birch. To these may be added woods of foreign growth—as rose-wood, satin-wood, and mahogany, which are employed for ornamental purposes.

According to another classification, trees are arranged as of three kinds—coniferous or resinous, hard-wooded, and soft-wooded. For the sake of clearness, we will adopt this simple arrangement, confining ourselves to trees which may be grown in the climate of Britain.

Coniferous Trees.

The obvious distinction of these trees is the production of cones containing their seeds; but they present other peculiarities. Their stems are usually tall and straight, bearing symmetrically arranged side-branches; and the wood-cells or wood-fibres, of which their timber is composed, exhibit under the microscope peculiar discs with a central dot—as shewn in the accompanying



Coniferous Tissue of *Wellingtonia gigantea* (280 diameters).

figure—which at all times serve to distinguish coniferous timber from that of all other families of plants, whether fossil or recent, even in a charred state.

The Coniferæ are not only useful timber-trees, but are also highly ornamental, their lofty trunks and pendent branches, clothed with peculiar evergreen foliage, rendering them conspicuous and pleasing objects in the landscape, either when grown singly or in groups or plantations. On this account, the Coniferæ have of late years received much attention from those interested in the improvement of estates; while the constant succession of new and useful additions that have recently been made to the lists of species suitable for our climate, has served to heighten the interest of this family of trees. The growth of Coniferæ has, in fact, assumed among the landed proprietors of the British Islands an aspect somewhat similar to the tulip-mania which rendered the Dutch florists so notorious; but there is one difference which we wish to keep in view in drawing this comparison—that while the Dutchman's 'fancy' only served to gratify a conventional taste, and to increase his fondness for gambling, the coniferous fancy, on the other hand, is doing good service to our country, in so far as it is yearly enabling us to grow more and better timber than was ever grown before in the British Islands. Keeping this fact in view, we can understand the reasons that actuate a proprietor in paying fifty guineas for a fir-cone: the timber which he may rear from the seeds it contains, is likely to give but a very inadequate return for such outlay; but he sees that future generations will reap the benefit of every really useful addition that is made to the timber-trees of Britain; and he deserves our best thanks for his generous devotion to our national prosperity.

Scots Fir (*Pinus sylvestris*).—This is a tall and generally straight tree, with few branches on the lower part of the stem, the foliage being confined to the top

of the plant, and there forming a massive clump. The numerous uses to which pine-timber is applied in this and other countries are well known. The Scots pine is indigenous to the northern parts of Europe and Western Asia, and forms vast natural forests in the Highlands of Scotland. It grows in almost any soil,

Scots Fir (*Pinus sylvestris*).

provided there be not a superabundance of moisture, and is justly valued as one of our most useful timber-trees. The two leading varieties are—1. The red-wooded or native; and 2. The white-wood, Haguenau, or continental Scots fir. Both are extensively grown; but a preference is usually given to the native sort, and especially to young trees grown from seeds saved in the indigenous forests of Scotland. Mr Brown gives judicious instructions for the growth of this tree, when he says: 'The best timber-trees for general purposes are raised where they are standing pretty close in one mass; but the tree assumes its most picturesque form when standing singly, with room to spread out its branches. When grown in one mass close together, the trees are found clean-stemmed, and drawn up to a great height; consequently such trees are available for many purposes; whereas, when standing singly, the tree is generally short-stemmed, thick, and branchy. No tree, a native of Britain, can with more safety be planted out into any soil and situation, provided only that soil be a dry one. I have seen a crop of good Scots fir taken off almost every sort of soil of an earthy or stony nature, but upon a mossy soil I have never seen good Scots fir timber grow.'

The Scots fir succeeds remarkably well in many of the northern parts of Scotland; but in the south, and especially in England, it is grown chiefly as a nurse to hard-wood trees, for which purpose its hardiness and rapid growth render it very suitable.

Weymouth Pine (*Pinus Strobus*).—The Weymouth pine produces a whitish-yellow wood, which is pretty hard, fine-grained, and easily worked; and being usually straight, this timber is much used for masts, bowsprits, &c. Lord Weymouth was the first proprietor who planted this tree extensively in Britain. It accommodates itself to most kinds of soils, but attains greatest perfection in valleys and on river-banks, where there is an accumulation of vegetable matter; so situated, it attains a height of from 150 to 200 feet, with a girth of stem of from 12 to 16 feet.

Corsican Pine (*Pinus Laricio*).—This tree yields a whitish resinous timber, darker towards the pith; it is coarse-grained, but easily worked, elastic, and durable, and is much used by the French in ship-building. In this country, it is not only a valuable timber-tree, but also a useful one for ornament, for it grows rapidly, and soon assumes a handsome pyramidal form. On a good light soil, it attains a height of from 100 to 130 feet, reaching maturity in the course of seventy or eighty years. It is a native of the south of Europe, chiefly occurring on high elevations; on Mount Etna, it grows between 4000 and 6000 feet above the sea-level, attracting attention by its huge, far-stretching roots, which creep over the rocks, and are exposed above the surface wherever the soil is shallow.

The 'Black Austrian Pine' is a variety of the Corsican Pine, having a flat spreading head. It appears to have even a greater adaptability for different soils than the normal form of the species; and the wood, which is very resinous, is much valued from its capability of resisting the effects of water, and of alternate moisture and dryness, which is even more trying for timber than constant immersion in water. So highly is this tree esteemed by many, that it is thought it may ultimately supersede the Scots fir; but the higher price of young plants has hitherto acted in some measure as a check upon its universal diffusion.

Cluster Pine (*Pinus Pinaster*).—This tree affords a soft, and not very durable wood, which is chiefly employed in making boxes, &c., and is better known in France than with us. The cluster pine, however, has strong claims upon our attention, for it is capable of producing timber on soils unfit for other plants. It is a southern European species, growing along the shores of the Mediterranean, and on the Apennines, to about 2800 feet above the sea-level. On wet soils, it will not grow; but wherever the soil is dry, even if exposed to the sea-breeze, it forms a handsome pyramidal tree, fifty or sixty feet in height. In France, it has been employed profitably to cover immense tracts of sand along the shore; and so far as it has been tried in similar situations in Britain, it has succeeded equally well. Resin is extracted by slicing the bark; and tar and lamp-black are obtained by burning the wood.

Spruce Firs constitute a well-known genus (*Abies*) of the Coniferæ, the more common being the Norway spruce (*A. excelsa*), a tree which attains great height, and furnishes white deal and spars; it is also very suitable for masts and poles of all kinds. The Norway spruce is now widely planted throughout Britain, particularly in the Lowlands of Scotland; and when enjoying a favourable situation, soon grows to a useful size. It is a hardy tree, and though its timber is softer and less durable than the Scots pine, yet, from the rapidity with which it grows, and its adaptation to a soil rather damp, it is frequently preferred.

In many parts of Northern Europe, it forms the principal timber; being known in the market as white deal or Christiania deal. When grown singly in a moist soil, the Norway spruce assumes a very handsome appearance, but it loses its beauty when grown in crowded plantations.

The *White Spruce* (*Abies alba*) is a North American species, whose root-fibres macerated, are used by the Canadian Indians as thread to sew their birch-bark canoes. It is associated with the *Black Spruce* (*A. nigra*), which is even a hardier species, growing in the most inclement regions. Its timber is very strong, light, and elastic, and is valuable for the yards of ships, and other purposes in which these qualities are required. The young branches yield essence of spruce, known to voyagers as an antiscorbutic.

Douglas's Fir (*Abies Douglasii*) is one of the most valuable of the numerous species introduced by that devoted traveller. It grows rapidly, but forms compact, heavy timber. It forms immense forests in

North-west America from 43° to 52° north latitude; the erect tapering trunks varying from 100 to 180 feet in height, and many of them nearly ten feet in girth. The bark of the young branches is swelled into globular receptacles of turpentine, and the wood-cells exhibit spiral fibres. The tree being very ornamental, and well adapted to our climate, is much sought after by cultivators, and is gradually superseding the larch, not being liable to disease. *Menzies' Fir* also produces timber of excellent quality.

The *Silver Fir*, called also the Pitch Fir (*Picea pectinata*), displays a greater depth of branches than the other firs, and becomes a majestic tree on arriving at full age. In this country, the silver firs are chiefly seen as objects of ornament on dressed ground. The quality of the silver-fir timber of British growth is rather indifferent. *Abies nobilis* is a magnificent tree, and many other species of the genus are in cultivation; such as the Indian, the Hemlock, Webb's, and the Balm of Gilead Fir.

The *Larch*.—Of this valuable genus (*Larix*) there are several species grown in Britain and other countries; the more common is the *L. Europœa*. The larch is one of the most beautiful of this class of trees; its straight elegant stem tapering to a point, and furnished with pendulous branches, which are ornamented with delicate drooping spray. It is of rapid growth; in many parts of the country, it has gradually superseded the common fir, over which it possesses a great superiority in point of ornamental effect; but of late years, the 'dry rot in larch' (as it is called) has served to discountenance its use for many purposes. 'There are,' says the authority already quoted, 'two varieties of the larch generally cultivated in Britain—the white and the red. The white is the variety which attains the greatest dimensions of timber, and is the sort most generally cultivated, although they are both often seen growing together in the same plantation, and that by mere accident. It is said that upon the Athol estates the red larch does not contain above one-third the cubic contents of timber which the white larch of the same age does; and this is observable in every plantation where the two varieties are found growing together. No timber-tree at present cultivated in our woods begins to repay the expense of culture so soon as the larch does. It is a rapid-growing tree, and is well adapted for almost every country purpose. It generally sells at nearly double the price per cubic foot that Scots fir brings; and besides the price of the wood, the bark is available for tanning. The circumstances which are found favourable to the healthy development of the larch are—as to soil it is not particular, but the roots must have a constant supply of water, in order to keep the earth in which they grow in a pure state, as is the case upon all rugged mountain-slopes where there is a continual descent of water from the higher ground to the lower.' On very arid soils, the larch never grows freely, and soon dies off with a stunted lichen-clad bole; and on flat ground, where water is liable to stagnate, though the young trees may succeed for a few years, yet they are never found to prosper, but die away as soon as the mere surface-turf is exhausted.

The *Cedar of Lebanon* (*Cedrus Libani*) is remarkable for its long horizontal branches, and the great mass of dark-green spicular foliage with which it is covered. It is a native of the mountains of Libanus and other high adjacent regions, where it attains great bulk, and grows to a very great age. From its solemn aspect, it forms a suitable accompaniment to ecclesiastical buildings or cemeteries, and also for sequestered glens in mountain scenery; it is equally well adapted for extensive lawns. Cedars were introduced into Britain as far back as 1683; and there are but few old country-seats that do not possess some specimens. Many majestic ones are met with in different parts; but in no situation have they thriven more prosperously than at the celebrated residence of Moor Park, in Hertfordshire. So numerous and large were they upon this estate—according to the *British Cyclopædia*—that about 1798 scores of them were felled for sale, containing four and five loads of timber in each of their stems alone. Cedars are trees of very striking character, and give an air of grandeur to every scene in which they appear.

Cedars may be raised from seeds which ripen in England, or from seeds imported from the Levant. When got from the cones, they are sown in seed-pans or boxes; and when fit for removal, the seedlings are nursed in pots, until they are large enough to be planted out in the open ground. While nurslings, many of them require a stake, to which a leader must be constantly kept trained, in order to insure a regular growth.

Deodar or *Sacred Cedar of India* (*Cedrus Deodara*). This is perhaps one of the most beautiful of the whole family of Coniferæ, its erect stem, and widely spreading, gracefully curved boughs, drooping at the tips, and clothed with the most beautiful green foliage. It grows on the mountains of Northern India, on heights of 10,000 or 12,000 feet. The Hindoos hold it in great veneration, calling it the Tree of God. Its wood is so durable, that specimens several hundred years old have been taken from Indian temples quite sound. Although the timber of this differs from that of the preceding species, still it is regarded by many botanists as in reality not specifically distinct. The deodar has been largely planted as an ornamental tree, during the last few years, being peculiarly suitable for pleasure-grounds, and especially for lawns and cemeteries.

Chili Pine (*Araucaria imbricata*). 'This noble tree,' says a recent writer, 'is, without exception, the greatest ornament among conifers;' and although still rare, is yearly becoming more common in pleasure-grounds. The male tree is said never to exceed 40 or 50 feet in height, while the female often attains 150 feet; but all the specimens in this country are as yet comparatively young. A deep light loamy soil is the most suitable for this tree. Its wood is yellowish-white, hard and durable, and well adapted for some ship-building purposes. It is regarded as quite hardy in Britain; but the early severity of the winter of 1856–7, browned the foliage of many specimens in different parts of the country, without, however, affecting their vitality.

The *Wellington Tree* (*Wellingtonia gigantea*). This is the great monarch of western forests, its gigantic proportions exceeding those of all other coniferous trees with which we are acquainted. According to Mr Lobb, it inhabits a solitary district on the elevated slopes of the Sierra Nevada, in latitude 38° north, longitude 120° 10′ west, at an elevation of 5000 feet above the sea-level; the trees there observed varied from 250 to 320 feet in height, and from 10 to 20 feet in diameter. One that was felled measured about 300 feet in length, with a diameter, including bark, of 29 feet 2 inches, at five feet from the ground; at eighteen feet from the ground, it was 14½ feet through; at one hundred feet from the ground, 14 feet; and at two hundred feet from the ground, 5 feet 5 inches. The trunk was perfectly solid. 'What a tree is this!' says Dr Lindley; 'of what portentous aspect, and almost fabulous antiquity! They say that the specimen felled at the junction of the Stanislau and San Antonio was above 3000 years old; that is to say, it must have been a little plant when Samson was slaying the Philistines, or Paris running away with Helen, or Æneas carrying off good *pater Anchises* upon his filial shoulders.'

This remarkable tree has been successfully introduced into this country by Messrs Veitch, through their collector Mr Lobb; and the young plants we have seen, appear to thrive well in our climate. To these gentlemen we are indebted for a specimen of the timber whence the microscopical drawing on page 579 has been taken, and we have also reproduced a portrait of the tree from their drawing. The timber is of a red colour, clean

and soft, resembling that of *Taxodium sempervirens* in general appearance.

The Wellington Tree (*Wellingtonia gigantea*).

The *Yew* (*Taxus baccata*) is more frequently grown as an ornamental than as a forest tree, and, like the cedar, it forms a plant suitable for places consecrated to solemn feeling. Its timber is very tough, and is adapted for making bows and staves, hence it is commonly ranked among hard-wooded trees. As an ornamental tree, it should be fenced round, or otherwise placed beyond the reach of cattle, as its foliage is highly poisonous; and being evergreen, is very apt to be browsed upon during the winter.

Yews are believed to be the most ancient planted trees of Great Britain; and no doubt can exist that there are individuals of the species in England as old as the introduction of Christianity, and there is every reason to believe very much older. It is the opinion of Decandolle, that of all European trees, the yew is that which attains the greatest age. The following are some of the more remarkable British specimens to which the attention of the curious has been directed. Those of the ancient Abbey of Fountains, near Ripon in Yorkshire, which yews were well known as early as 1155. Pennant says, that in 1770 they were 1214 lines in diameter, and consequently, according to Decandolle's method of computation, were more than twelve centuries old. Those of the churchyard of Crowhurst in Surrey, on Evelyn's authority, were 1287 lines in diameter. There are two remarkable yews still in the same cemetery, and if they be the same that Evelyn refers to, they must be fourteen centuries and a half old. The yew-tree at Fortingal in Perthshire, mentioned by Pennant, in 1770, had a diameter of 2588 lines, and consequently we must reckon it at from twenty-six to twenty-seven centuries old. The yew of Brabourn churchyard in Kent is said to have attained the age of 3000 years; that at Hedsor in Bucks, however, surpasses all others in magnitude and antiquity; measuring above twenty-seven feet in diameter; thus indicating the enormous age of 3240 years!

Hard-wooded Trees.

In this class are included a large number of trees with which every one is familiar. The list embraces—the oak, ash, elm, beech, chestnut, walnut, common sycamore, mountain-ash, whitebeam, acacia, birch, wild-cherry, laburnum, holly, hazel, box, and hawthorn. The following are the principal:

The *Oak* (*Quercus*) is the most valuable of all the timber-trees grown in Britain, not only because it is a hardy native, but for the many important purposes to which its durable timber, its astringent bark, and even its nutritious fruit, are applicable; and, moreover, for the delight which it gives to the eye in sylvan landscapes, the oak being the most picturesque tree of the forest when it has arrived at its mature age and form, and is still clad with foliage.

There are two species in our woods, natural or planted—namely, the *Q. Robur*, whose acorns grow singly and with long stalks; and the *Q. sessiliflora*, whose fruit grows in clusters, with short acorn stalks. The former is said to be the old Druidical British or naval oak, though the latter is more frequently met with, especially in woods which have been planted by the hand of man. Besides these two common sorts, which are natives, there are many other species, which are exotics—namely, the willow-leaved, the evergreen, ash-leaved; holly-leaved, of which there are six shrubby varieties; chestnut-leaved, scarlet, white, Italian, durmast, Luccombe, and the Turkey, of which there are four varieties, &c.

All the species are readily raised from their acorns. The young plants are transplanted twice or thrice in the nursery; and when four or five years from the acorn, may go to their final stations. Any kind of clayey loam is suitable for the oak; but a good gravelly loam, upon a subsoil of blue ferruginous clay, produces the finest timber in the shortest time. 'The largest oaks I have ever seen,' says Mr Brown, 'grew upon a dry sandy loam, with a free exposure to air; however, although the

The Oak.

oak may attain its greatest dimensions under such circumstances as these, we find it growing to the size of useful timber wherever it has the advantage of a soil with a dry bottom, and not too much exposed to storms—as, for instance, upon the top of a bare hill. The oak will not thrive or live long in a damp mossy soil.'

England, as well as Scotland, at one period possessed many noble and remarkable oak-trees, the remains of which are in some instances still to be seen, while in others they are only remembered in tradition.

The *Ash* (*Fraxinus excelsior*) is also a very valuable hard-wood tree, its timber being useful for many rural purposes, and particularly for implements and machines

The common ash, being prolific in ripening seed, is dispersed pretty generally over the face of the British isles. It should never be allowed a place in a hedgerow or on pasture-land, as its numerous surface-spreading roots absorb every particle of moisture, to the destruction of all other surface-plants. The circumstances favourable to the healthy development of the ash are, as regards soil, a good strong loam, rather rich than otherwise, and rather moist than dry—for the ash does not disagree with a little moisture, provided that this moisture have free and ready escape from the roots, and is not liable to remain in the least degree stagnant. The ash is also rather fond of shelter, and therefore, to grow it well, it is an advantage to plant it in a hollow or glen, or in the interior of a large plantation.

An ash-tree is in its prime, when by free and vigorous growth, it has attained a diameter of about twenty inches; for though on rich gravelly loam it will continue to increase until it is four or five feet in diameter, it has probably begun to rot at the core long before it has arrived at that vast bulk. Therefore, in order to raise ash-timber of the most valuable description, it is necessary to sow or plant a piece of land of the above character thickly, placing the trees about two feet apart. These will rise rapidly; and as soon as they appear to be choking each other, one half of the poles may be drawn, and the rest allowed to stand till they arrive at a marketable size, which is when they are from eight to twelve inches in diameter, and from forty to sixty feet high. When *ground-ash* is of these dimensions, it is suitable for every mechanical purpose where flexibility and extreme toughness are required. From its upright habit of growth, the ash forms one of our best forest-trees; and what is especially deserving of notice, its timber is better—that is, more tough, elastic, and durable—the more rapidly it is grown.

Seed should be gathered in the autumn, and immediately sown in nursery-beds; or the sowing may be deferred till spring. Some of the seeds may not rise till the second or third year; but as soon as the seedlings are five or six inches high, they should be rowed out to gain strength till finally transplanted. There are several varieties of the common ash, one of which is the weeping-branched, which, by grafting high on the tall stem of the common ash, forms a very ornamental weeping-tree.

The *Elm* (*Ulmus*) is a lofty tree, valuable both for its use in the arts and its ornamental appearance. The small-leaved or English elm is generally preferred for planting, particularly in hedgerows, avenues, and the like. This tree is not a forester, never being seen but about dwellings, or where dwelling-houses have formerly stood.

Besides the common wych-elm (*U. campestris*), found wild in the hedges of Britain, and which grows, where allowed, to a large size, yielding coarse-grained but useful timber, there are several other sorts. All delight in a gravelly loam, or in any soil which is not too wet; and they are well worth the planter's attention. No tree bears lopping or pruning better than the elm, it being hardly possible to hurt it by dismemberment. In the forest, it requires considerable space, as its natural habit is to throw out on every side broad spreading branches. When confined, it grows up with a slender weakly trunk, the timber of which is of little use to the carpenter.

The elm attains a very large size, and has a very rapid growth, both in Europe and America; but the elm of the latter country has a much more majestic appearance than that of Europe. Michaux characterises it as 'the most magnificent vegetable of the temperate zone.' A specimen mentioned by Decandolle, which grew near the town of Morges in Switzerland, measured 17 feet 7 inches in diameter, and was estimated at 335 years of age.

The *Beech* (*Fagus sylvatica*) is a native forest-tree, occurring most commonly on the chalky districts of the kingdom. When full grown, it is a beautiful and stately tree; and its timber is convertible into many kinds of domestic articles, very durable when polished by the cabinetmaker, and equally so if kept constantly under water.

Young plants are readily raised from the seed sown on beds, and covered with loose soil about an inch thick. Like other seedlings, they are, when five or six inches high, rowed out on fresh ground, till large enough to be transferred to their final stations. The beech is not at all fastidious as to soil; but a subsoil of chalk or limestone is most congenial. According to Mr Brown, few trees suffer less from mismanagement than the beech; and upon thin, poor soils, and even in high and exposed situations, no hard-wooded tree is so worthy of a place. He has seen the beech grow well upon a soil and situation where scarcely any other tree could have existed, not even the Scots fir. There are several species; the white-American, the dark-purple, and the dark-leaved, are ornamental, and are propagated by grafting on the common. As a forest-tree, none of the species are now extensively planted, in consequence of the comparatively little value set upon beech-timber.

At Newbattle Abbey, the seat of the Marquis of Lothian, a few miles south from Edinburgh, attention has been drawn to some remarkably fine large trees, most probably planted by the monks prior to the Reformation. Professor Walker measured a beech at this place in 1789; its trunk, where thickest, was seventeen feet in girth, and the span of the branches was eighty-nine feet. He thought that it must have been planted between 1540 and 1560. It was blown down a short time before the year 1809. It contained upwards of 1000 measurable feet of timber—twenty loads, or twenty-five tons—and was with reason reckoned among the largest beeches ever grown in Scotland. Another at Taymouth, of a like size, and seemingly coeval with this, was blown down when it had reached more than sixteen feet in girth. The large beech at Ormiston Hall, in Haddingtonshire, the bole of which we remember to have seen scooped out artificially into a shelter-house, was measured on the 10th of May 1762, and found to be eighteen feet ten inches in circumference. We believe it was quite entire when it was destroyed by a high wind. A large beech near Oxenford Castle, in Mid-Lothian, was measured on the 6th of June 1763. At the height of three feet from the ground, its circumference was nineteen feet six inches. This fine tree was then decaying.

The *Chestnut*, or sweet chestnut, sometimes also called the Spanish chestnut (*Castanea vesca*), is a splendid forest-tree, exceeding all other British plants in its huge mass of foliage; it is also valuable for its timber, which is but little inferior to the oak. In the south of Europe, it is chiefly regarded as a fruit-tree; but here, even in the south of England, in the finest summers, the fruit ripens but imperfectly. As a timber-tree, however, the Spanish chestnut deserves to be more generally planted than it has been of late years; and for a coppice or underwood plant it has no superior. For the number, the straightness, and durability of its poles, it excels all others, when a little trouble is taken to keep the growth perfectly regulated with respect to the purpose for which the crop is wanted. When timber or ornament is the object, the trees must constantly be divested of the shoots, which are apt to rise from the stem. A strong loamy gravel seems to suit this tree best; and young plants are easily raised from the nuts, dibbled in rows in the spring, and while in the nursery, kept free from bottom-shoots. The sweet chestnut requires considerable shelter, in order to permit of its full development; and should always be cut down before arriving at maturity, as the heart-wood is very liable to decay.

The *Common Walnut* (*Juglans regia*) is chiefly

regarded as a fruit-tree, but it is no less valuable for its excellent timber, which, from its lightness, durability, and beauty, and the high polish it takes on, is well adapted for house furniture, and is almost the only wood used for gun-stocks. Where its fruit is of no great value, and especially where it does not ripen, if planted among other forest-trees, it would be drawn up into a shapeable single stem, as valuable as many others. Young trees are readily raised from the nuts, like the chestnut, and are similarly managed.

The *Sycamore* or *Plane-tree* (*Acer pseudo-Platanus*) is a hardy native tree, which attains a large size, and grows more quickly than most of the other hard woods. It is employed for many common purposes, and in turnery. It not only grows to a large size, but lives to a great age. It prefers a dry sandy loam, with free exposure, but may be profitably planted in almost any situation, except in damp or mossy soil. The Oriental plane is one of those trees which attain the largest size, but the rate of its increase is not ascertained. In the valley of Bujùkdére, about three leagues from Constantinople, there is a plane which recalls to mind one which Pliny has celebrated. According to the Roman naturalist, there was a plane-tree in Lycia which had a hollow trunk capacious enough to accommodate the consul Licinius Mutianus and eighteen followers, who found within its ample cavity a retreat for the night. This living vegetable grotto was seventy-five feet in circumference, and the summit of the tree resembled a small forest. The plane at Constantinople is 150 feet round, and within it there is a cavity of 80 feet in circumference. This transcends the tree of Pliny. There are other very large Oriental planes mentioned by Clark and others; and one of vast size was lately noticed by Mr Quin in his voyage down the Danube.

The *Mountain Ash* (*Pyrus Aucuparia*), familiarly known in Scotland as the *rowan-tree*, from its beautiful clusters of red rowans or berries, is a tree of small dimensions, but elegant form, and is grown principally for ornament in shrubberies. It is hardy and of easy growth in dry soils, and makes an excellent skirter or outside tree in ornamental clumps and plantations; its finely formed foliage and white blossom yielding variety in summer, and its deep red berries as striking a variety in autumn and early winter. It should not be planted in town gardens or squares, as the berries attract the attention of mischievous boys.

The *False Acacia* (*Robinia pseud-Acacia*) is not only a highly ornamental, but also a valued timber-tree, when allowed to attain a proper size. Though a native of Virginia, and there called the *locust-tree*, it has been recommended as a coppice-plant for this country, on account of the very quick growth of its young shoots, which rise from roots after the stem is cut over; and for the excellent and durable quality of the poles for fencing, and particularly as props for hops and other trees. But whether planted thickly for underwood, or more openly for timber, the acacia requires much attention from the pruner during the first five or six years of its growth. It produces large luxuriant lateral shoots, which, if not stopped by having their points pinched off when they are about one foot long, are very likely to be blown off by the wind. This care may cease after the tree or pole is ten or twelve feet high, for after that height the growth becomes moderate. Young plants are raised from seeds or from layers, and thrive on any light sandy soil. The timber is highly prized by mill-wrights for cogs and other friction purposes.

The *Wild Cherry* or *Gean-tree* (*Cerasus Avium*) is a hardy native, but is seldom cultivated as a timber-tree; nor is that care bestowed upon it which it really deserves. The best specimens to be met with are those which have grown by accident in woods; but when such are felled, they are readily purchased by the cabinet-makers. The wood is very suitable for boring and for forming musical instruments. It is therefore a tree not to be neglected by the general planter, and should have a place among others. Young plants are raised from the stones, sown thickly on a bed of good soil, either in autumn or in spring, and afterwards rowed out to receive the ordinary nursery treatment, until fit to be finally planted.

The *Hornbeam* is an inferior forest-tree; its timber, however, is remarkably tough and durable, and consequently valuable to the plough and cart wright. It is a tortuous-growing tree, unless pruned when young.

The *Birch* (*Betula alba*) is another inferior timber-tree, but useful, as a coppice-plant, for many rural purposes. It has a beautiful and elegant contour, on which account it is introduced into ornamental scenery, especially if water be in the composition. Of the common birch there are several varieties, not to speak of the poplar-leaved, the tall, and the black American. Young plants are most conveniently raised from seeds, and the exotic species are raised from layers, &c. Wherever there are poor thin-soiled stony heights, the birch may be planted as a useful cover; its timber is readily bought up for gunpowder charcoal.

The *Holly* (*Ilex Aquifolium*) is a remarkably hardy evergreen, with smooth shining leaves furnished with prickly points. It is a native of Britain, and attains a great age, but seldom reaches a large size. Its timber is white and hard, which renders it suitable for veneering, and for making mathematical instruments. Different varieties are grown as ornamental shrubs. The holly hedges of Tyninghame, in East Lothian, have long been famed, being 11 feet broad, and from 18 to 25 feet high.

The *Box* (*Buxus sempervirens*) is generally grown as an evergreen shrub, but when planted out with a proper soil and climate, it attains a considerable height. *B. balearica* grows to perfection in Turkey, whence its timber is imported for use in all cases in which exceedingly fine cross grain is required. Sawn across and planed, its surface is as smooth and fine as polished metal. Box-blocks are on this account employed for wood-engraving.

Soft-wooded Trees.

In this section may be included the horse-chestnut, lime, alder, poplar, and willow.

The *Horse-chestnut* (*Æsculus Hippocastanum*) is only valued for the beauty of its flowers and the majesty of the full-grown tree in park-scenery. The timber is very inferior. There are several other exotic species—namely, the smooth, Ohio, ruddy, and the pale-flowered, all of which are easily raised from their large nuts. They require shelter and good rich soil; they grow rapidly under these conditions, and soon form highly ornamental objects. A section of this genus is called *Pavia*, or bucks-eye, the fruit being round and smooth. The flowers of some of these last are magnificent, being of a glowing red, and are most conspicuous in the spring or beginning of summer. Avenues of these trees, as seen in the neighbourhood of Geneva, present a gorgeous appearance when in flower. The pavias are often propagated by being grafted upon the common horse-chestnut.

The *Lime* (*Tilia*) is a beautiful leafy tree, grown chiefly for ornament, and very suitable for avenues. As all the varieties require a heavy soil and sheltered situation, and their timber is not of corresponding value, they are seldom or never introduced into the forest. The lime is the European tree which, in a given time, appears capable of acquiring the largest diameter.

The *Alder* (*Alnus glutinosa*) requires a damp bog-earth soil, and is only planted by streams, or to occupy a spot where nothing better will grow. It is most profitably kept as underwood, large poles suitable for the turner or for piles or planking for bridges, fetching a good price.

The *Poplar*.—There are several species—as the common black poplar (*Populus nigra*), the trembling poplar,

the Lombardy poplar, &c. They grow rapidly, and the last mentioned rises to a great height, but narrow in mass, so as to be very conspicuous in hedgerows and landscapes. The timber is soft, but a good deal sought after; and where undrainable spots are wished to be decorated with stately trees, no better kind can be chosen.

The *Willow* (*Salix*) is an extensive genus, comprehending those shrubby species, the osiers, used for basket-work, as well as a few species which attain to the height and character of trees, the best of which, as yielding very good timber, is the white or Huntingdon (*S. alba*). Another of the tree-willows is that elegant plant the Babylonian or weeping willow, which forms so suitable an accompaniment to pieces of water, whether artificial or natural. The common osier is the sort mostly cultivated for the basket-maker, and the annual crop of rods from established stools pay the owner as well as any other crop on the farm. All the kinds are easily propagated by cuttings, and require to be grown in wet soil.

REARING OF TREES.

Trees grow spontaneously in all countries in which soil and climate will permit, and, as is well known, form forests of many hundreds of miles in extent on the North American continent. Whatever be the peculiar nature of any species of tree, it appears that the dimensions and form of all are more or less affected by their relative situation. If crowded, they have a tendency to grow tall and slender; if left abundance of space, they extend in breadth. The comparative absence or presence of air and light causes this. In a forest, each tree struggles upwards; whereas the tree in open ground shoots out lateral branches nearly from the bottom of the trunk, and attains a mass of foliage.

All exposed trees have the largest roots; being liable to be blown over, they take a much firmer hold of the ground than if they were sheltered on all sides; in other words, the action of the tree, and the free air and light, induce the development of numerous branches and a large breathing apparatus of leaves, and the tree must have a corresponding mass of roots for the supply of sap. So exact is this correspondence between the exposed and underground portions of the tree, that the extent of roots may sometimes be judged by the extent of branches. The practical lesson acquired from these facts is, that if trees are to have large bushy heads, they must be planted widely; and if wanted to be tall and slender, they should be crowded.

Ornamental Plantations.

Even on the smallest possessions, a sprinkling of forest-trees in the hedges or corners of the enclosures gives a dignity to the spot which otherwise it would not possess. There cannot be a more cheerless object in a landscape than a house—however substantially built—standing naked and alone, without a sheltering tree or bush to indicate either the taste or competence of the occupiers within. The lowliest hut, environed by two or three aged oaks or hawthorns, is an interesting spectacle, and far more delightful to the eye than the proudest palace standing bare and unaccompanied by trees.

In ornamental planting, there is much room for the display of good taste. It is now allowed by all who have studied landscape-gardening, that in the part surrounding the mansion, trees should not be dotted about at equal distances, nor in lines, neither should they be placed as blinds to the principal windows, but so arranged as to form irregular glades, diverging in as many directions from the house as is consistent with effect and propriety. These glades should always be laid out with reference to some distant interesting object, or some striking feature of the surrounding country. The offices, which are generally in the rear, or at one end of the house, should be hidden by a screen of trees and shrubs; and all eyesores, visible from the windows or elsewhere, should also be screened by plantation.

When it is intended to increase both the beauty and the value of an estate by planting, either for the personal interest of the proprietor, or with a view to that of posterity, ordinary prudence will direct him to fix on those parts which are the least valuable for agricultural purposes. The precipitous slopes of an undulating surface, where cultivation is difficult or impracticable, moist swampy hollows, or the ridges of bleak hills lying to the northward or eastward, will all be found eligible for conversion into woodland. And while such plantations yield the finest shelter and cover for game, they rapidly add to the real value of the estate.

It has already been observed that some proprietors may think it advisable to plant only the inferior portions of their property; while others, who wish to have a tastefully planted park or a highly embellished estate, place their groves, or groups, or single trees, on any eligible spot, without regard to the quality of the soil. In this case, everything is sacrificed to obtain such a disposition of the trees as will produce the most striking scenic effect; and such kinds only are selected as blend harmoniously with each other.

The character of the general surface surrounding a mansion fixes the style of planting and the kinds of trees. If the surface be moderately undulating, having easy swelling knolls and gently falling hollows, without asperities of any kind, such a surface is said to be beautiful, and consequently the plantations should be beautiful also; that is, composed of trees of the finest foliage and most elegant forms. But if, on the contrary, the surrounding country be wild in character, and marked with bold and rugged features, as naked rocks or cliffs, deep ravines or glens, &c., then a different style of decoration must be pursued —as planting in irregular masses all the most grotesque, rugged, and sombre-tinted trees that can be selected, in order to harmonise with the natural features of the country. Scenery of this kind is said to be picturesque; and where such tracts of country are chosen for a manorial residence, and the grounds are laid out and planted by a skilful gardener, the scenery is much more interesting to the eye of taste than any other, especially if water chance to be in the composition. The grounds of Dawick, in Peeblesshire, afford a fine example of ornamental plantations, which have been increasing in beauty for many years, under the taste and management of their proprietor, Sir John Naysmith, Bart.

Great changes occurred in the style of planting during the eighteenth century. Up to the beginning of the reign of George I., all transplanted trees were arranged in right lines, as single, double, or quadruple avenues or vistas, or as boundaries to the enclosed grounds belonging to royal or other palaces, colleges, and public buildings. But about this time it was discovered that trees in rows were rarely seen in the works of the great masters in the schools of painting: a new idea was entertained that such a disposition of trees was inadmissible, as being too stiff, formal, and not agreeable to nature; a sentence of condemnation was accordingly passed upon private avenues, and they quickly disappeared before the axe of the woodman. A few only were saved, and now comparatively few avenues are planted. Along with the avenues, the old regularly laid out terraces and flower-gardens were swept away to make room for a new style, distinguished by the prevalence of *irregularity* and *curved outlines*.

Soon after this revolution in landscape-gardening, a great many ridiculous pranks were played in

obtaining *extreme* irregularity and *tortuous* lines; and some of the performers got severely handled by the satirists of the day. Kent, who began the revolution, died without having gained much reputation; but his successor, the famous 'Capability' Brown, became highly eminent, and was universally employed. He did more in altering the gardens and grounds of the country-seats of these kingdoms than any landscape-gardener before or since his time. His aim was to produce unmixed beauty by neatness and general smoothness, especially near the house; for which purpose he cleared away every obstruction, whether built or planted, in order to set the mansion fairly out upon a naked grass-plot or lawn. Even the kitchen-gardens were removed as far off as possible; and every bush, or other appearance of inequality, was shaven off, to produce the wished-for smoothness. In this proceeding he and his copyists fell into the opposite extreme; instead of beauty, *baldness* was the result; instead of intricacy, *tameness;* and instead of the embosoming shelter of surrounding groves, complete nakedness, and exposure to every wind that blows. Nevertheless, Brown had the honour of laying out many beautiful parks and gardens, which remain to this day as monuments of his good taste and judgment; but many of his immediate followers brought discredit upon his style by their very awkward and unmeaning imitations.

The severe animadversions published against the Brownian style tended to correct some of its author's most ostensible errors; and the works of Repton, Loudon, and others, have improved the style of English landscape-gardening, and brought it much nearer to the principles of real taste. The *clump* and the *belt* have been greatly modified; the first is now expanded into a less formal group, and while the latter has lost its continuity, it has been increased in depth, and its lengthened form as a boundary judiciously broken. Undergrowths, which were swept away by Brown, are again introduced; and the banks of lakes and rivers, formerly smoothed down to the water-level, are now left more abrupt, broken, and irregularly fringed with overhanging trees, and aquatic shrubs and herbs.

Forest-planting.

The different methods pursued in establishing or laying down woodland, depend in some measure upon the number of acres and the nature of the ground. Nevertheless, there are certain points which in every case are worthy of the planter's attention; such as the best form for any given extent, the style of boundary, and the mode of enclosure. On these heads we transcribe the advice of a practical forester of long experience. 'As the future welfare of a plantation is considerably affected by the manner in which it is laid out, no man ought to attempt the laying out of ground, who is not naturally possessed of good taste for that sort of landscape scenery, which is based upon the laws of nature, and which will enable him to lay out the proposed plantation in such a manner as to give the greatest possible effect in ornamenting the neighbouring country. It is also necessary that the person who would lay out ground for a new plantation, should be possessed of a knowledge of the nature of the growth of each sort of tree when planted upon any given soil or situation; which knowledge will enable him to judge rightly as to the effects that certain trees will have when planted in any given spot; and he will also be enabled from such knowledge to say truly whether or not trees will grow well in the situation chosen for a new plantation. It is further necessary, in the laying out of a new plantation, that he should be acquainted with, or at least have in view, any local peculiarities of the district relative to cold and destructive winds from certain points. From such knowledge he will be able to lay out the proposed plantation in such a manner that it shall have the greatest possible effect in giving shelter to the surrounding fields, which is the principal end a proprietor aims at in having woods upon his estate.

'The larger that any piece of plantation is, the sooner will the trees come to useful size, and answer the desired end; the smaller it is, the more likely are the hopes of the planter to be disappointed. And the reason of this is obvious: for the young trees growing in an extensive plantation, as soon as they rise a little above the surface of the grass or heath, begin to shelter one another; whereas if the plantation be narrow, the young trees can hardly be said ever to come the length of sheltering one another—for every breeze of wind blowing through the whole breadth, acts upon every single tree almost as powerfully as if each tree stood singly and alone. Therefore, it is most profitable for proprietors always to plant in large masses. Trees planted in a mass of one hundred acres' extent will be more healthy, and come sooner to profitable size, both as affording timber and shelter, than they would if planted in a mass of ten acres. From this it follows, that if a proprietor wishes to plant one hundred acres upon his estate, he will raise more healthy timber by planting in one mass, than he would do by planting the same extent in four masses of twenty-five acres each. No young plantation, upon an exposed situation, should be less than one hundred yards broad at any given point; and where the soil is of a light, thin, mossy nature, and not apt to raise trees to good size, one hundred yards may even be too little for breadth.'

Again: 'The method of laying out plantations in the form of strips, so often to be met with in Scotland, gives a poor and mean appearance to a gentleman's estate, particularly when found about the home grounds. The form in which they have generally been made is in straight lines, from twenty to thirty yards broad. In such narrow belts of wood, the trees are very seldom found in good health; and, upon a little consideration of the matter, this is not to be wondered at—because, from the narrowness of such strips, the proprietors were always afraid to thin them, wishing to keep them in a thick state, in order to give as much shelter as possible; and the natural consequence is, from being left too thick, the one tree soon kills the other. And even where such strips have been well managed, it cannot be expected that they could produce either good healthy timber or make a good shelter; for, being so narrow, the trees never come to shelter one another. But it is a happy circumstance in the history of arboriculture, that few such strips are now planted: gentlemen are now beginning to see the impropriety of such a method of raising plantations; and now, in almost all cases of good management, we see the old-fashioned narrow strip giving place to the well-defined, extensive plantation, which is, indeed, the only profitable way of rearing trees for any economical purpose.'

Further: 'It is absolutely necessary that every piece of ground laid out for a plantation should be fenced in some way or other, previous to its being planted. A fence not only prevents the inroads of sheep and cattle, but it at the same time tends very much to shelter the young trees, and to bring them on rapidly. It is, indeed, surprising to observe the difference that a very low fence makes upon the growth of young trees, as compared with those which are not protected by one. Any proprietor or forester, upon looking through his several plantations, will observe that, in all young plantations, the most rapid-growing, and at the same time the most healthy trees in it, are to be found immediately behind the outer fence; and, upon the other hand, in all older plantations, the best grown, and at the same time the most healthy trees, are to be found in the centre of the same, or at least a considerable distance back from the fence. Now, it may be asked, what is the reason that the best wood is found in

the inner parts of old plantations, while the most rapid-growing trees are to be found, when young, behind the boundary-fence? The reason, as proved from experience, is this: During the first eight or ten years of the age of any young plantation, the boundary-fence is the only shelter that the young trees have; and it is evident that those trees which grow immediately behind the fence will receive most of the benefit of its shelter; consequently, from the circumstance of their receiving more shelter than their neighbours further off, they grow more rapidly, until such time as their tops begin to rise above the level of the fence, when they are considerably checked by the cold winds. At this stage they begin to grow thick and bushy, rather than advance in height; and immediately upon their becoming so, they begin to shelter all their neighbours inside, which, again, begin to have double the advantage of their neighbours outside; for the trees upon the outside had shelter only so long as they were below the level of the top of the fence, whereas those inside have now a shelter which every year increases upon them for their advantage, in height as well as in thickness. All this goes to prove that a fence is a great means of furthering the healthy development of a young plantation, independent of its protecting from the inroads of cattle at the same time. I always calculate that a plantation with a good fence is ten years in advance of one without such protection.'—*Brown's Forester.*

We must now notice the more approved practice applicable to the better kind of soils. In one of the prize-essays of the Scottish Arboricultural Society, published in the Transactions (1857), Mr Thomson, of the Royal Forest, Chopwell, offers the following valuable observations on this head: 'Planting is a work of the greatest importance, and cannot be satisfactorily executed unless there is due preparation made for it. We often see large tracts of land surcharged with water, and growing only the veriest rubbish, having a few forest-trees studded at irregular intervals over the extent; but such is not planting in the true sense of the word. We apprehend the first thing necessary to attend to in this respect is, to have the grounds carefully laid out into the required form, which, as a matter of course, will have to be regulated by the natural undulations and general outline of the grounds upon which the plantation is to be formed, and the position and aspect which it is desired it should assume. It will, however, be found advisable, in all cases where practicable, to have one side made as much as possible in a convex (or cuneate) form, with the tip of the cone pointing in the direction whence the prevailing winds of the district blow; this is in order that the force of severe gales may be broken, and not allowed to burst with their full force upon the whole body of the plantation at once. This is a consideration of paramount importance everywhere, but more especially in high-lying and exposed districts. The next step is to have the land properly fenced, in whatever manner may be found cheapest and most efficient; whether by stone-dikes, thorn-hedges, or wire-railing, must depend upon local circumstances and individual judgment and taste. Following immediately upon this, drainage of the land, in all cases where found necessary, should be carried out. Having these preliminary particulars fully completed, and having determined upon what kinds of plants are required, the next step—and a vitally important one it is—is to make a careful selection of the plants that are to be employed. This is a duty no forester who consults his employer's interest, or who has respect for his own character and professional standing, will neglect, seeing that if diseased or otherwise inferior plants are obtained, the whole operation will inevitably end in failure and disappointment, and the expense both of plants and planting will have to be again incurred; and not only so, but the diseases which most commonly infest nursery stock are of a very contagious nature, and will, to a certainty, contaminate the whole adjoining neighbourhood; and when they once obtain a hold in any district of country, it is by no means an easy task to effect an eradication. The greatest judgment and care must therefore be exercised in the selection of forest-trees; it must be seen that both roots and stems are free from bug or other disease, and that they are of a size suitable for the soil, situation, and climate wherein they are to be planted.'

With respect to the choice of trees for different soils and circumstances, Mr Thomson observes:

'With a view to profit only, larch should be more extensively planted than any other kind of tree, as it grows very rapidly, is in constant demand, and generally sells at a remunerative price. Approximate calculations shew that two crops of larch can be brought to maturity in the same space of time required to bring one of oak to perfection; and supposing that both are equally well situated as regards external circumstances, the several sums realised for the former, with accumulated interest, will more than double the amount of income derived from the latter. The timber of the larch is suitable for a great variety of purposes, and, with the single exception of the ash, can be more generally appropriated to mining and country uses than that of any other kind of tree our land produces. When it is grown upon good sound land, and found close and firm in the texture, it is in many cases preferred to the best Memel; and I could name many instances where it has been selected while the other was rejected. The larch will grow healthily on almost any kind of soil free from extreme dampness, but it is not advisable to plant it on very light or sandy land; on which it soon exhausts all the amount of nourishment the soil affords, and prematurely decays. . . .

'The oak, also, is a tree which will be planted as long as planting continues. Deep loamy soil, or a mixture of clay and loam, upon a rocky formation, is the best adapted for its rapid growth; but from the far-spreading and searching nature of its roots, it will thrive on what is termed "bare rocky ground," if there is sufficient depth of soil wherein its roots may become firmly established; and when once established, it is well known the amount of endurance it will undergo rather than relinquish its hold. On light or gravelly soils, the oak ought not to be planted, as it very soon becomes stunted in its growth upon all such, and never succeeds to large or profitable dimensions. The oak is also valuable on account of the bark it produces, which is employed in tanning. The ash and elm are somewhat similar to the oak in their natural characteristics, and can be successfully grown under much the same general circumstances; only, to grow healthily, the land upon which they are planted should be considerably drier than such as the oak will succeed well in, though it also delights in a dry soil. If dampness pervades the soil upon which these trees are planted, both kinds, but more especially the ash, will soon become covered over with moss and lichen, from the injurious tendency and effect of which it is next to impossible to relieve them. Neither should they be planted upon gravelly soils, as I have observed that in all such cases they invariably decay at an early stage of their growth; and though they may continue to *exist* for a moderate length of time, they do not proportionally increase in bulk and stature, and must therefore, as a natural sequence, become deteriorated in quality. Where all these kinds of hard-wooded trees—the oak, the ash, and the elm—succeed best, is on a loamy or alluvial soil, with a subsoil of clay, situated upon a substratum of rock or gravel. In marshy places, or along the margin of lakes, water-courses, &c., the birch, the alder, and the poplar may be planted to any extent, as they luxuriate in low-lying grounds, which being their natural habitat, is of course most congenial to their growth. The birch will also grow well on moderately dry lands.

'All these trees are undoubtedly natives of Great Britain, and in the northern parts of the island are frequently to be met with, of themselves forming extensive and valuable plantations. They frequently grow to large dimensions, and possess the additional advantage that they will succeed where scarcely any other forest-tree would thrive, and but for which, vast tracts of land would be allowed to remain perfectly waste; whereas, with their use, the very poorest may be turned to profitable account. For planting on light or gravelly soils, the Scots pine should be principally selected, seeing that it flourishes upon the poorest lands, and in the most exposed situations. The *Pinus Austriaca* has to a certain extent superseded the planting of Scots firs during the last few years, and is *supposed* to constitute a good substitute; but its general applicability to the soil and temperature of Great Britain not having yet been fully tested, and possessing, as we do, but little information of its quality as a timber-tree, it would appear to be unadvisable that it should be introduced to the entire exclusion of our own native pine. The timber of the Scots fir is useful for many purposes, and, when fully matured on land favourable to its growth, far surpasses in quality much of the timber imported from foreign countries; whilst no other tree whatever equals in amount the shelter it affords. Even in the most mountainous and exposed districts, and on the barest lands, it thrives in an extraordinary manner; and considering that it combines, in an eminent degree, extreme hardness with general practical utility as a timber-tree, and seeing that it possesses such powers of contending successfully against difficulties in the form of soil, temperature, and aspect, we would earnestly advise that, instead of allowing it to become obsolete, more and more attention should be bestowed on the culture of the real native sorts, and that it should be more extensively planted than ever. The spruce fir also thrives well on light soils; and where the temperature is mild and humid, it forms an excellent tree for admixture with others of various sorts. It will not, however, endure the same amount of exposure as the Scots pine, and should not, therefore, be planted at any considerable altitude; but in moderately elevated situations, it may, with propriety of taste and judgment, be largely introduced, as the shelter it affords is of the greatest consequence to plants of a more delicate nature, and it likewise possesses such natural beauties as to warrant its being cultivated in all woodland scenery. The beech and sycamore, if not altogether so hardy, without doubt, stand next in that respect to the Scots pine, and will grow most luxuriantly on even the poorest of soils.

'With reference to the beech, I have seen it attain to large dimensions on pure sand; but the soil best adapted for bringing this tree to the greatest perfection, is a marly or gravelly clay on a chalk formation, on which it attains to the most elegant stature and beauty. In the south of England—in some cases exposed to the severity of the south-west gales—it grows in a comparatively short space to the most admirable dimensions; and though its timber, on account of its brittleness, is inferior to that of most other hard-wooded trees, the natural and picturesque gracefulness of a good specimen of the beech is such as to command for it a prominent position in every gentleman's park; and, with a view to ornament, we would be fully disposed to class it amongst the first of our indigenous trees. The sycamore also delights in a light soil, and being of a very hardy nature, will thrive well, and may be profitably grown on exposed situations, either by the sea-shore or on high-lying districts. Its timber is of considerable value when of large size, and is applied to many useful purposes. Upon the whole, the sycamore and the beech are much akin in their natural habits, and may be grown under circumstances almost identically the same.'

The same authority observes: 'In no case does it appear to me advisable that hard-wooded trees should be planted alone or in excessive numbers; for even if a hard-wood plantation be desired, it is better, in the first instance, to plant the requisite sorts amongst a variety of the fir tribe, so that they may be duly sheltered and protected in their youth. Both kinds should also be planted at the same time. We have seen many examples where the nurses have been planted a few years before the hard-wooded trees were put in, preparatory to which last, certain quantities of the firs had to be removed; but the practice is antiquated, and indisputably a bad one, simply because it produces the very effect which it is intended to avoid. Ostensibly, this is the production of an abundance of shelter, or that the hard-wooded trees may grow more exuberantly than they otherwise would do; but it ought to be recollected that the firs grow much more rapidly than any hard-wooded tree which is cultivated for the sake of its timber, and doing so, completely shade and overtop the more valuable sorts, to the entire exclusion of both light and air, without which it is absolutely impossible that any plant in the whole vegetable kingdom can prosperously succeed. The system I myself practise is—first, to determine at what distances apart the hard-wood trees ought to be placed—say from nine to twelve feet—and having these carefully put in, I next proceed to have the spaces between these plants filled up to suitable distances with firs which have been selected for the purpose. On low-lying grounds, the distances between the plants, over all, need not be less than from three and a half to four feet, beyond which it is unnecessary to extend them, as the thinnings, at even this rate, will be of some small value when the operation of thinning is first required; but on more exposed and colder situations, the rate of planting may be reduced so low as even two and a half feet from plant to plant. The best nurses are larches, Scots pine, and spruce firs; and they may very advantageously be planted in the ratio of two of the former to one of either of the latter, as such a course will be found to be equally beneficial with any other, and decidedly the most profitable.

'As to the time or season of the year when planting operations may be most satisfactorily executed, I would unhesitatingly record the matured opinion I have derived from extensive observation and practical experience, that all such should be conducted and concluded in the four months of November, December, January, and February. . . . On damp lands, and where late spring-frosts prevail, planting may be postponed till the very latest of the dates I have noticed; but if prosecuted beyond this, the operation cannot reasonably be expected to succeed. If the plants are to be put in by the system of what is technically called *pitting*, the pits may be prepared any time before; and the longer previously they are so prepared, so much the better, as the soil cast out of the pits, being exposed to frosts and the ordinary action of the weather, becomes thoroughly pulverised and purified; and is thus put into a sound and healthy state for the reception of the roots of the young trees.

'With regard to the *method* of planting, I consider it preferable in all cases to prepare pits for hard-wooded trees of all kinds, as they require a considerable space to develop the large fibrous roots with which they are, or ought to be, furnished. The dimensions of these pits must be regulated by the size of the plants they are designed to contain. In ordinary cases, I would say that pits from twelve to fifteen inches in diameter would suffice for every necessary purpose; they should also be made perfectly circular, and fully as wide at the bottom as the top. Pitting will also be requisite for all kinds of firs, where planted on stony or any kind of hard ground; but in loamy, or any other sort of friable soil, I find the ordinary system of notching to be

decidedly the best, and by far the cheapest. Where, however, pitting is found to be indispensable, I would advise that the expense of casting the soil actually out of what may be termed the pit, and replacing it again, should not be incurred; as, if it is well stirred all round to the required dimensions with the end of the mattock—the utensil employed in this service—the whole advantage resulting from the system of pitting is equally well secured, the plants are more easily put in, and the cost is comparatively trifling. Trenching may also be found necessary in some isolated cases, but the enormous expense it incurs precludes its general application, even though it were advantageous in every instance, which is not the case. However planted, the utmost care must be exercised, so that none of the roots of any fir may be cut off with the edge of the spade, which is too often done by ignorant or careless labourers; and though not easily detected when committed, this species of injury is doubtless the parent of many of the casualties which occur in the earlier years of some of our plantations. Due regard must also be had to the *sizes* of plants most suitable for different localities, with respect to situation and climate; for moderately sheltered grounds, I would say that oaks about one and a half foot high, one and two years' transplanted larch, two years' transplanted Scots fir and spruce, would be found to be the most suitable; on more exposed situations, two years' seedling larch, with one year transplanted spruce and Scots fir, will answer better than those of a larger size.'

When a large extent of *inferior* land is intended to be planted, it must necessarily be executed in the most economical manner, and without many of the preparations above recommended. If the surface be irregular, and covered with short herbage, two or three year old plants of larch, Scots fir, birch, intermixed with a few oak, beech, and ash, may be inserted at proper intervals by forming notches in the turf. One or two blows of the tool raises a triangular piece of the surface, under which the root of the plant is properly placed, and the raised sod turned back and trodden down with the foot. In this simple and expeditious way of planting, many hundred acres of hilly land have been stocked with trees; and though many of the plants are liable to suffer, if a dry summer follows the planting, a majority are sure to succeed, which well repays the cost. Notwithstanding the risk of being defeated in such attempts, it is quite certain that in numberless cases they have succeeded admirably; and very valuable woods now ornamenting both England and Scotland have been raised under these simple modes of planting. When such ground is level, an opening is made by first cutting the turf in the shape of a cross, and turning back the four corners from the centre, breaking up and making a hollow for the root; when the tree is placed upright, the turf is returned and trodden firmly down.

But in planting rough unprepared ground, especially where it is very hard, it will sometimes be found advisable to incur the expense of *pitting*, even where the pits have not been prepared beforehand, as above recommended. The surface-covering is first cleared off, the pit broken up with a mattock, and the loose earth thrown out with a spade; the tree is then placed, and planted with the removed soil.

Before planting, it is always necessary, as we have stated, to see that the land is properly drained, otherwise good timber cannot be produced, and it may be advisable to notice briefly some of the points to be kept in view in draining. The number and extent of the drains will be regulated by the extent of plantation and wetness of soil, which will also indicate the proper distances apart. A depth of between one and a half to three feet is recommended by Mr Rutherford, who, in the *Transactions of the Scottish Arboricultural Society*, makes the following judicious observations on this subject:

'Before commencing active operations in any portion of land about to be drained for planting, great care must be taken in the selection and provision of a proper outfall. This is of such vital importance, that, were it not attended to, the whole drainage might be rendered totally inefficient, or, in fact, it could not be executed at all. On level land this is more particularly the case, and its perfect execution, both in laying out and cutting, resolves itself into an absolute necessity. Where a large tract of level land has to be drained—a circumstance not likely often to occur—this superfluous absorption causes an increased evaporation from the stem and leaves, the consequence of which is, that a lower natural heat prevails in the plant, and the chemical changes on which its growth depends proceed with less rapidity. The air ought to be able to penetrate into the soil, being, as it is, so essential to the preservation of a proper temperature and to the ramification of roots; and this it can never do in soils where there is an excess of water. To remove, then, this free water, which is the source of so many evils, the cause of so much disease, and the destroyer, consequently, of many sanguine expectations, ought to be the first care of every arboriculturist. Unless this be attended to, no successful result can be attained; the progress of plantations will be tardy; the individual members of them will become deformities, when they would have been ornaments; they will become sickly and die, when they would have been healthy, and yet growing vigorously. . . . The principal object in view in draining wet land is, to cause the whole of the rain-water falling upon the surface of the ground to penetrate readily to a desired depth, and to discharge this water at once, not allowing it to accumulate in the subsoil. This done, the soil becomes pervious, and is then in a fit state for the operation of the planter.'

When ornamental plantations are made in a park, and especially if they are in view from the principal windows, it is desirable that they should rise as quickly as possible, for the sake of immediate effect; the trees, therefore, receive careful treatment. The ground is not only deeply trenched, but a most liberal dressing of good rotten dung and vegetable mould—the first trenched down, and the latter dug into the surface—is bestowed, which of course excites the trees into much stronger and more rapid growth than if only the ordinary expedients were employed. But this superior and expensive practice is seldom necessary, and much seldomer executed. Indeed, in the rearing of extensive forests for valuable timber, it would be decidedly injurious; for though the young trees might rise rapidly for a few years, as soon as the exciting influence of the manure was over, they would, as all experience teaches, soon fall into a diseased condition, and never attain that hardy robustness which natural forest-timber always presents.

Pruning—Thinning.

When woods are planted as a source of profit, a material part of their subsequent management consists in the labour of pruning and thinning the trees. It is not enough that trees shall grow and be annually increasing in bulk; they should also be assisted to take the finest and most valuable forms, and this in fact greatly affects their increase. A round straight bole, of moderate length, is more useful and saleable than a crooked knotty one of twice the size. To have fine timber, it is absolutely necessary to bestow a little trouble to start them fairly off, during the first ten or fifteen years of their growth.

To have tall and straight stems, the trees are planted thickly at first, about four feet apart, or even less; and if in the spring the woodman pays his annual visit, armed with a light keen bill, he may direct the growth with the best effect. Every lateral branch that appears to be attracting too much of the powers of the plant, and especially if, as already observed, it be contending

for supremacy with the leader, should be cut off *close* to the bole as soon as it has attained the diameter of an inch. Such a wound will be soon healed up, and present no flaw when the tree is cut up at the saw-pit. If branches are allowed to remain until they have acquired a diameter of from two to four or more inches, and then cut off either close, or, what is much worse, at some distance from the bole, the timber is deteriorated. Such wounds will be healed over in time, but the timber will be wanting in its best property—namely, soundness and freeness from knots.

Trees grown for ornament in lawns require no other pruning than what may be necessary for the removal of rotten or decaying branches; and in general it will be found advisable to leave each kind of tree to assume its own natural form. Ornamental trees are always most beautiful in their proportions when the branches and spray tend towards the ground; but this will not be the case if cattle are allowed to browse beneath and around them. These animals nibble away all the foliage and spray within reach, so as to form an even bottom of foliage, anything but agreeable to the eye. The only plan of avoiding this inelegance is to exclude browsing animals altogether from ornamental grounds; but this is attended with opposite evils, and takes away that pleasing assemblage of forms which is the great charm of woodland scenery. Where cattle or sheep are permitted to browse, all young trees at least must be protected by circular palings, otherwise they would be barked, and generally destroyed.

All species of the hardy pine and fir tribe intended for profit should be planted pretty thickly, and thinned when young, leaving a full number of permanent trees to grow up to a marketable bulk. The fine clear-grained timber imported from America and the north of Europe is the produce of trees which were never pruned; growing up in very close order, the lower spray is consecutively killed by the want of air and light, shut out by the close canopy of branches above. This is gaining sound timber by accident, which may be done in any country, but by no means in such a short time as by hand-pruning.

Mr Philip, of Aldbar, states that trees increase in thickness fastest when they have about two-thirds of their whole height covered with branches during the whole period that they are increasing in height; these ought to be diminished to between one-half and one-third of the height for a top, according to the sheltered or exposed situation they may be in, care being taken not to draw them up too fast, and then allow them to get top-heavy, as this would bring on too much strain both on root and stem, which in soft soils is very injurious to the tree. 'Every tree,' he observes, 'has its own habit; and the pruner must, in a great measure, adapt himself to the habit of the tree he has to deal with, and not force them into any shape which may please the fancy of the operator. We can only assist nature in her operations. One tree such as the poplar, has a natural tendency to keep to one leading shoot, and to keep its branches within a comparatively narrow space; while the oak has the opposite tendency, if left to nature: its habit is to have a short stem with a wide-spreading top, which may be a beautiful object in certain situations, but certainly not profitable as a timber-tree. Pruning is so closely connected with, and dependent on judicious thinning, that attention to it is of great consequence; for to thin the trees to wide distances will cause them to throw out strong side-branches, and this creates additional work to the pruner; but by keeping the trees pretty thick on the ground, the branches are confined within reasonable limits, and consequently kept from increasing to a large size. The method which I adopt is, by thinning and pruning, to keep the trees standing quite clear of each other, to allow free circulation of air, and admit the light all round them—both of which are essential agents in the growth of trees; and by this means I manage to keep the trees in a healthy growing state, and prevent the branches from becoming large, which always detracts from the value of timber, except where bends and *knees* are formed fit for ship-building. The tools which I use in the operation of pruning are—a strong pocket-knife, hand-saw, a saw with the teeth reversed, and the pruning-shears; the last two are fixed on long poles, and they save much loss of time in climbing: for trees further advanced, a ladder fourteen to eighteen feet will be found necessary.'

Transplanting.

Trees may be lifted from one place to another, or transplanted. The art of accomplishing this exceedingly delicate operation was chiefly developed by the late Sir Henry Steuart of Allanton. The transplanting of a full-grown tree has in all ages been deemed next to impossible; and when it was attempted, the operator thought it necessary to cut off a great number of the branches—and consequently the leaves—from an idea that, if suffered to remain, they would require more sap than the roots could supply in their new situation; but this practice was found to be injurious.

Sir Henry Steuart practised the art of transplanting on what he called the preservative principle—without mutilating either roots or branches. His seat, Allanton House, was situated on an irregular slope, on the right bank of the river Calder, a tributary of the Clyde. The neighbouring ground, though diversified, had no very picturesque natural points; but he contrived, by the removal of large trees, and forming an artificial lake and river, to realise in some measure the miracle of bringing new and picturesque scenery into actual existence, in a short period of time.

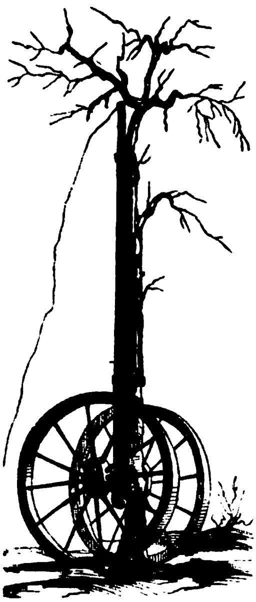
When single trees are to be planted on a lawn, a space of from four to six feet is stripped of the turf, which is rolled back; the soil within should be deeply broken up and excavated, to receive the full spread of the roots. A heap of rich loam or compost is laid in the centre, on which the tree is placed, and the roots are covered with the same, and watered, to consolidate the earth about the fibres. The other soil is then thrown on, and the turf returned to its place and beaten down firmly. Single trees should be staked; and if on a pasture, a cradle will be requisite to defend them from the browsing or rubbing of cattle.

Much has been written on the subject of transplanting *large* trees, and many successful exploits of this kind have been performed both in past and present times. Shady groves have been formed in the short space of a few months; proving that, with care, skill, and physical force properly directed, any tree of moderate size may be transplanted with safety and success. One precaution very much facilitates the execution: it is that of digging a circular trench at a proper distance, say six feet, round the trunk, and deep enough to be below, and to cut through all the roots except three or four of the largest, which are left at equal distances to act as spurs for the better security of the tree when placed in its new situation. The trench, after the stumps of the roots are cut smoothly off, is filled with prepared compost, for a new fringe of roots to strike into, and after one or two years, the tree is in a condition for removal.* In doing this, a deeper trench is made on the outside of the first, into which the mould from among the roots is drawn, until the whole are loosened from the soil; the spur-roots are also followed out and laid bare. The method of raising the tree by a machine is mentioned below. In replanting, much depends on laying out the roots, and firmly imbedding them in moistened earth, and also adding a pretty heavy covering of soil round the stem, to keep the tree steady against wind.

A machine for transplanting has been long in use,

* The renovation of decayed trees is effected in a similar manner.

on the principle of the common timber-truck—being a strong lever attached to the axle-tree of a pair of wheels. The latter are strongly constructed. The axle-tree is correspondingly substantial, and to its middle the pole or lever is securely fixed. The pole should be made of the best ash, seven inches square, with the edges planed off, and somewhat reduced in thickness towards the end. The length should be at least ten feet, for the longer it is, the greater the purchase in raising a tree. The pole is strengthened by side-braces let into the axle, and mounted with an iron eye and ring at the point. When used, it is backed against the tree, and the pole is raised and made fast thereto, as here represented. The wheels rest in the hollow made by baring and loosening the roots; and when all is ready, the strength of men, or that of a horse, is applied to the pole-chain, which is, together with the tree, pulled to the ground, the root being lifted out of the soil; and, when thus borne on the machine, it is drawn away, root foremost, to its new place, previously prepared for its reception. The wheels are drawn into the new opening, the pole and tree are set at liberty, and if the root be heavy, the tree will resume its former position with but very little assistance. The machine is then loosened from the tree, and removed; the roots are laid out carefully, and imbedded in loose soil, and the whole is finished by a copious watering.



When a machine is made on purpose for removing large trees, the axle-tree may be made to fit a pair of cart-wheels for a temporary purpose; but the axle should be formed with *straight*, not *drooping* ends, as they are usually made, because this facilitates the raising of the pole. Upon the upper side of the axle there should be a thick block of wood bolted, to give more elevation to the root when drawn along; and on this an old sack, or a thick band of straw, is bound, to prevent chafing the bark of the tree.

Many improvements in the apparatus used for transplanting have been introduced of late years, one of the most important of which is that of Mr M'Glashen (patented), by which he is enabled to lift trees of any dimensions. It consists of a number of large spades so arranged as to enter the soil around the tree, and raise it with an attached ball of earth, so that the roots are not disturbed, those extending beyond the ball being cut through. By a peculiar construction of carriage, &c., the ball of earth can be boxed up, and conveyed to any distance without separating from the roots. Mr M'Nab, of the Edinburgh Botanic Garden, has also introduced a system of transplanting, which has been long in use in the Botanic Garden, and is fully described in the *Scottish Gardener* and *Gardeners' Chronicle*. This method is not restricted to trees, but is also applicable to the re-tubbing of palms and other unwieldy plants, the same apparatus being available for both purposes. The many improvements that have of late years been introduced in the disposition of the trees and shrubs in the Botanic Garden, have been effected by means of Mr M'Nab's system.

Coppice—Live-fences.

Coppice or underwood is either natural or planted. Natural underwoods are often the remains of ancient forests which are kept enclosed, and are felled periodically at long or short intervals, according to the purpose for which their produce is to be applied.

Thriving and well-fenced and well-managed coppice is in some cases more profitable than timber-woods. Timber and coppice may be united; the standard trees to stand thinly, and if kept pruned up, the undergrowth is not much hurt by their shade. Mixed underwoods are cut every five, seven, or ten years, unless they are entirely of oak, when they are allowed to stand longer, for the sake of having larger poles, together with the bark, which last is a principal part of their value. On the subject of oak-coppice, Mr Brown remarks, that the value of the bark has fallen so much of late years, as to render the exclusive growth of this kind of underwood no longer a source of real profit. 'About twenty-five years ago the price of oak-bark was £16 per ton; while this year (1847) the highest price that has been given in Edinburgh is £5, 10*s*.*—making its value at the present time only about one-third of what it was twenty-five years ago, and consequently reducing the value of oak-coppice plantations in the same ratio; and upon this consideration, I do think that proprietors should not, at the present time, rear up oak-plantations with the intention of converting them into coppice, as has in many instances been done of late. I have seen plantations of healthy oak-trees, about thirty-five years of age, cut down for the sake of the bark they produced, and with the view of converting them into coppice-wood, so as to have a crop of bark every twenty-five years afterwards. Now, had those trees which were cut down at thirty-five years of age, been allowed to grow for other forty or fifty years, they would of course have attained their full magnitude, and been worth to the proprietor, at the end of that period, more than three times the money that he could get as the produce of the same plants if cut down and disposed of in the form of coppice-wood at periods of twenty-five or thirty years. No doubt, where old plantations are cut down, it is right and proper that the stocks of them should be converted into coppice-wood, for this is taking advantage of growths which can be converted into use, and which would otherwise be lost; but to raise up trees to a certain age, and then cut them down prematurely for the sake of their bark, is at best an enormous loss to the proprietor as well as to the country in general.'

For live-fences, except in peculiarly bleak and barren situations, hawthorn is the best adapted; care, however, is required both in the planting and trimming. There is a general complaint that thorn-hedges do not thrive well; but in most cases the want of success will be found to arise from improper treatment. The preparation of the land for planting hedges requires the greatest care, for if this be not cleared of weeds before the thorns are planted, it will be almost impossible to do it afterwards. Foul land should be well fallowed before the hedge is planted; and if poor, it will require to be manured. Old pasture-land should be pared and burned, and the ground otherwise well prepared for the reception of the hedge. If possible, the ground should be trenched to about eighteen inches deep, and four feet in breadth, the surface-soil being placed in the bottom of the trench; and this will be found an excellent way of getting rid of weeds. The expense attending a thorough preparation of the soil will be amply repaid

* Returns now before us from foresters in different parts of the country, shew the prices at the time we write (April 1857) to vary from £5, 5*s*. to £6, 15*s*. per ton; so that the price seems rather to have increased than otherwise since the date of Mr Brown's calculation.

by having a clean and well-growing hedge, which is a great ornament to an estate. Indeed, so convinced are most landed proprietors of the advantages of a thorough preparation, that the soil is now not only cleaned and trenched, but supplied with a compost of lime and ditch-clearings—a treatment which immensely facilitates the growth of the thorns at the most critical period of their existence.

The season for planting depends in some measure on the nature of the ground; for if this be very dry, the planting should take place in the autumn, or early in spring, in order that the plants may have made some root before the heat of summer sets in. The autumn is recommended by some as the best season for planting on all soils, and the month of February by others; but perhaps it is immaterial which period be chosen. If spring is the time fixed upon, it should be as early as possible, so that the plants may not have made progress in vegetation before transplanting. There are various modes of planting hedges, some preferring the even ground, others forming a mound, with a ditch at one side, and planting either at the top or on a shelf in the side of the mound; others, again, making a ditch on each side of the mound. If the land be good and dry, the hawthorn will grow quite well upon the level ground; but if the soil be of a wet nature, either one or two ditches will be required. The thorns should be planted at the distance of about three or four inches apart, and about the same depth as they stood in the seed-bed. The plants should then be covered with the finest mould, the points little more than projecting from the front of the mound. A wooden fence may be required to protect the young hedge until it has acquired size.

After being planted, the hedge should be carefully gone over two or three times a year, to cut up weeds. This operation must be performed until the plants have reached some height, and the weeds are completely eradicated, after which the usual cleaning at the roots once a year will be quite sufficient. The plants should never be cut till after three years old, for if cut when younger, the hedge becomes stunted, and is never so healthy. Hedges, when properly established, should be regularly pruned once a year.

When hedges get bare and thin at the bottom, they ought either to be cut over by the root, or to have their sides dressed up close to the principal stems. There is another method of repairing thorn-hedges, which is called *plashing*. It consists in cutting half through the stems adjoining the gap to be repaired, and then bending the upper portion over the vacancy, fastening them down by stakes, or by warping them into each other. By this means a live-hedge is formed more speedily than by planting young shoots, and more effectually than by inserting dead branches. The bent stems soon send out shoots; and if the plashing has been done with care, and that on moderately young and pliant branches, it will be found to be a cheap system, but not permanently efficient.

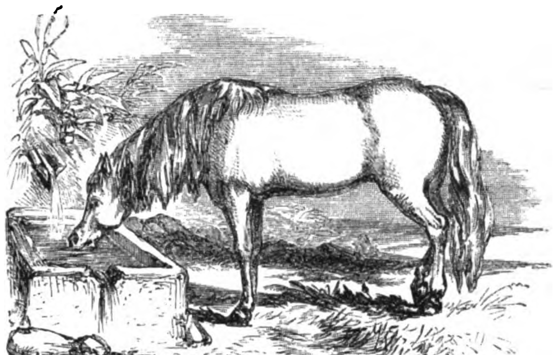
When thorn-hedges are cut too close by the ground, the decayed stocks should not only be taken out, but the earth where the stocks stood should be replaced with good fresh soil. The thorn-plants intended for filling up blanks should be carefully selected from such as have been transplanted two or three years, have stood thin in the nursery-bed, are well rooted, and free growers.

In high exposed situations, having thin moorish soils, or on hilly land composed of decomposed granite, thorn-hedges are seldom if ever found to thrive. In such situations, the beech has proved itself superior to every other plant, either as an assistant or a substitute for thorns. It retains possession of the soil, and continues to thrive when thorns decay or die out; and when regularly and judiciously cropped, it forms a compact fence, which few animals will attempt to break through. Indeed, experience has proved that, as a hedge-plant, the beech will thrive in any climate or soil; and what is of essential importance, it retains its leaves during winter, giving a genial warmth and shelter, besides being highly ornamental.

A very durable hedge for high situations with a light soil, may be formed by an admixture of thorn and beech plants in the proportion of two of the former to one of the latter. Such a fence not only looks well, but lasts well, if trimmed with due care and regularity. Latterly, furze or whins have been employed with advantage as fences. Many other shrubs and trees are used in live-fencing. Among the most common of these are the holly, the privet, and the yew, all of which bear pruning and training almost to any degree.

In maritime situations, where shelter is most wanted, such hedge-plants as the hawthorn and beech do not succeed; but the sea-buckthorn (*Hippophäe rhamnoides*) forms an admirable substitute. When well cared for, it may be trained into a neat and effective hedge, and does not suffer from the sea-breeze, even in the most exposed situations. The plane has also been recommended as a sea-side hedge-plant, but is inferior to buckthorn.

Cedars of Lebanon.



THE HORSE.

THE horse is universally acknowledged to be one of the noblest members of the Animal Kingdom. Possessing the finest symmetry, and unencumbered by those external appendages which characterise many of the larger quadrupeds, his frame is a perfect model of elegance and concentrated energy. Highly sensitive, yet exceedingly tractable, proud, yet persevering, naturally of a roaming disposition, yet readily accommodating himself to domestic conditions, he has been one of the most valuable aids to human civilisation—associating with man in all phases of his progress, from the temporary tent to the permanent city.

In ordinary systems of zoology, the horse is classed with the *Pachyderms*, or thick-skinned animals—as the elephant, tapir, hog, hippopotamus, and rhinoceros. Differing from the rest of the class in many respects, he has been taken as the representative of a distinct family, known by the name of *Equidæ* (*equus*, a horse), which embraces the horse, ass, zebra, quagga, onager, and dzegguetai. All these animals have solid hoofs, are destitute of horns, have moderately sized ears, are less or more furnished with manes, and have their tails either partially or entirely covered with long hair. The family may, with little impropriety, be divided into two sections—the one comprehending the horse with its varieties, and the other the ass, zebra, and remaining members. In the former, the tail is adorned with long flowing hair, the mane is also long and flowing, and the fetlocks are bushy; the latter have the tail only tipped with long hair, the mane erect, and the legs smooth and naked. The colours of the horse have a tendency to *dapple*—that is, to arrange themselves in rounded spots on a common ground; in the ass, zebra, and other genera, the colours are disposed in stripes or bands more or less parallel.

By his physical structure, the horse is fitted for dry open plains that yield a short sweet herbage. His hoof is not adapted to the swamp; and though he may occasionally be seen browsing on tender shoots, yet he could subsist neither in the jungle nor in the forest. His lips and teeth, however, are admirably formed for cropping the shortest grass, and thus he luxuriates where many other herbivorous animals would starve, provided he be supplied with water, of which he is at all times a liberal drinker. Delighting in the river-plain and open glade—the savannas of America, the steppes of Asia, and the plains of Europe, must be regarded as his head-quarters in a wild state. There is doubt expressed, however, as to the original locality of the horse. The wild herds of America are looked upon as the descendants of Spanish breeds, imported by the first conquerors of that continent; those of the Ukraine, in Europe, are said to be the progeny of Russian horses abandoned after the siege of Azov in 1696; and even those of Tatary are regarded as coming from a more southern stock. Naturalists, therefore, look to the countries bordering on Egypt as in all likelihood the primitive place of residence of this noble animal; and it is generally believed that the Arabian breed, when perfectly pure, presents the finest specimen of a horse in symmetry, docility, and courage. Regarding the horse as of Asiatic origin, we now find him associated with man in almost every region of the habitable globe. Like the dog, ox, sheep, and a few others of the brute creation, he seems capable of accommodating himself to very different conditions; and assumes a shaggy coat or a sleek skin, a size little inferior to that of the elephant, or not larger than that of an English mastiff, just as circumstances of climate and food require.

In a state of nature, the horse loves to herd with his fellows; and droves of from 400 to 500, or even double that number, are not unfrequently seen, if the range be wide and fertile. The members of these vast droves are inoffensive in their habits, and when not startled or hunted, are rather playful and frolicsome; now scouring the plain in groups for mere amusement, now suddenly stopping, pawing the soil, then snorting, and off straight as an arrow, or wheeling in circles, making the ground shake with their wild merriment. It is impossible to conceive a more animated picture than a group of wild-horses at play. Their fine figures are thrown into a thousand attitudes; and as they rear, curvet, dilate the nostril, paw in quivering nervousness to begin the race, or speed away with erect mane and flowing tail, they present forms of life and energy which the painter may strive in vain to imitate. They seldom shift their stations, unless compelled by failure of pasture or water; and thus they acquire a boldness and confidence in their haunts which it is rather unsafe to disturb. They never attack other animals, however, but always act upon the defensive. Having pastured, they retire either to the confines of the forest, or to some elevated portion of the plain, and recline on the sward, or hang listlessly on their legs

for hours together. One or more of their number are always awake, to keep watch while the rest are asleep, and to warn them of approaching danger, which is done by snorting loudly, or neighing. Upon this signal, the whole troop start to their feet, and either reconnoitre the enemy, or fly off with the swiftness of the wind, followed by the sentinel and by the older stallions. They are seldom to be taken by surprise; but if attacked, the assailant rarely comes off victorious, for the whole troop unite in defence of their comrades, and either tear him to pieces with their teeth, or kick him to death.

There is a remarkable difference in the dispositions of the Asiatic and South American wild-horses. Those of the former continent can never be properly tamed, unless when very young, but frequently break out into violent fits of rage in after-life, exhibiting every mark of natural wildness; while those of America can be brought to perfect obedience, and even rendered somewhat docile, within a few weeks, or even days. It is difficult to account for this difference in temper, unless we suppose that it is caused by climate, or rather by the transmission of domesticated peculiarities from the original Spanish stock.

SUBJUGATION AND DOMESTICATION.

As in South America we have the most numerous herds, and the most extensive plains for their pasture, so it is there that the catching and subduing of the wild-horse present one of the most daring and exciting engagements. If an additional horse is wanted, a wild one is either hunted down with the assistance of a trained animal and the *lasso*, or a herd are driven into a *corral*—a space enclosed with rough posts—and one selected from the number. The latter mode is spiritedly described by Miers, whose account we transcribe, premising that a lasso is a strong plaited thong, about forty feet in length, rendered supple by grease, and having a noose at the end: 'The corral was quite full of horses, most of which were young ones, about two or three years old. The chief guacho—native inhabitants of the plains are called peons or guachos—mounted on a strong steady animal, rode into the enclosure, and threw his lasso over the neck of a young horse, and dragged him to the gate. For some time, he was very unwilling to leave his comrades; but the moment he was out of the corral, his first idea was to gallop off; however, a timely jerk of the lasso checked him in the most effectual way. The peons now ran after him on foot, and threw a lasso over his fore-legs, just above the fetlock, and twitching it, they pulled his legs from under him so suddenly, that I really thought the fall he had got had killed him. In an instant, a guacho was seated on his head, and with his long knife cut off the whole of the mane, while another cut the hair from the end of his tail. This, they told me, was a mark that the horse had once been mounted. They then put a piece of hide in his mouth, to serve for a bit, and a strong hide-halter on his head. The guacho who was to mount, arranged his spurs, which were unusually long and sharp; and while two men held the horse by the ears, he put on the saddle, which he girthed extremely tight. He then caught hold of the animal's ear, and in an instant vaulted into the saddle, upon which the men who held the halter threw the end to the rider, and from that moment no one seemed to take any further notice of him. The horse instantly began to jump in a manner which made it very difficult for the rider to keep his seat, and quite different from the kick or plunge of our English steed: however, the guacho's spurs soon set him agoing, and off he galloped, doing everything in his power to throw his rider.

'Another horse was immediately brought from the corral, and so quick was the operation, that twelve guachos were mounted in a space which I think hardly exceeded an hour. It was wonderful to see the different manner in which different horses behaved. Some would actually scream while the guachos were girthing the saddle upon their backs; some would instantly lie down and roll upon it; while some would stand without being held, their legs stiff, and in unnatural positions, their necks half bent towards their tails, and looking vicious and obstinate; and I could not help thinking that I would not have mounted one of those for any reward that could be offered me, for they were invariably the most difficult to subdue.

'It was now curious to look around and see the guachos on the horizon in different directions, trying to bring their horses back to the corral, which is the most difficult part of their work; for the poor creatures had been so scared there, that they were unwilling to return to the place. It was amusing to see the antics of the horses; they were jumping and dancing in various ways, while the right arm of the guachos was seen flogging them. At last they brought the horses back, apparently subdued and broken in. The saddles and bridles were taken off, and the animals trotted towards the corral, neighing to one another.'

To hunt down the horse in the open plain requires still greater address, and greater strength of arm. According to Captain Hall, the guacho first mounts a steed which has been accustomed to the sport, and gallops him over the plain in the direction of the wild herd, and circling round, endeavours to get close to such a one as he thinks will answer his purpose. As soon as he has approached sufficiently near, the lasso is thrown round the two hind-legs, and as the guacho rides a little on one side, the jerk pulls the entangled horse's feet laterally, so as to throw him on his side, without endangering his knees or his face. Before the horse can recover the shock, the hunter dismounts, and snatching his *poncho*, or cloak, from his shoulders, wraps it round the prostrate animal's head. He then forces into his mouth one of the powerful bridles of the country, straps a saddle on his back, and bestriding him, removes the poncho, upon which the astonished horse springs on his legs, and endeavours, by a thousand vain efforts, to disencumber himself of his new master, who sits composedly on his back, and by a discipline which never fails, reduces the animal to such complete obedience, that he is soon trained to lend his whole speed and strength to the capture of his companions.

The subduing of wild specimens in America, the Ukraine, Tatary, and other regions, must be regarded as merely supplementary to that domestication which the horse has undergone from the remotest antiquity. A wild adult may be subjugated, but can never be thoroughly trained; even the foal of a wild mother, though taught with the greatest care from the day of its birth, is found to be inferior to domestic progeny in point of steadiness and intelligence. Parents, it would seem, transmit to their offspring mental susceptibility as well as corporeal symmetry; and thus, to form a just estimate of equine qualities, we must look to the domesticated breeds of civilised nations. At what period the horse was first subjected to the purposes of man, we have no authentic record. Trimmed and decorated chargers appear on Egyptian monuments more than four thousand years old; and on sculptures equally, if not more ancient, along the banks of the Euphrates. One of the oldest books of Scripture contains the most powerful description of the war-horse; Joseph gave the Egyptians bread in exchange for horses; and the people of Israel are said to have gone out under Joshua against hosts armed with 'horses and chariots very many.' At a later date, Solomon is said to have obtained 'horses out of Egypt, and out of all lands,' and to have had 'four thousand stalls for horses and chariots, and twelve thousand horsemen.' Thus we find that in the plains of the Euphrates, Nile, and Jordan, the horse was early the associate of man, bearing him with rapidity from place to place, and aiding in the carnage and tumult

of battle. He does not appear, however, to have been employed in the useful arts of agriculture and commerce; these supposed drudgeries being imposed on the more patient ox, ass, and camel. Even in refined Greece and Rome, he was merely yoked to the war-chariot, placed under the saddle of the soldier, or trained for the race-course.

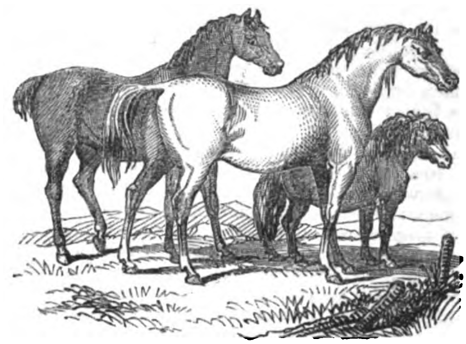
As civilisation spread westward over Europe, the demands upon the strength and endurance of the horse were multiplied, and in time he was called upon to lend his shoulder indiscriminately to the carriage and wagon, to the mill, plough, and other implements of husbandry. It is in this servant-of-all-work capacity that we must now regard him; and certainly a more docile, steady, and willing assistant it would be impossible to find. But it is evident that the ponderous shoulder and firm step necessary for the wagon would not be exactly the thing for the mail-coach; nor would the slow and steady draught, so valuable in the plough, be any recommendation to the hunter or roadster. For these varied purposes, men have selected different stocks, which either exist naturally, or have been produced by a long-continued and careful system of breeding. In a state of nature, the horse assumes various qualities in point of symmetry, size, strength, and fleetness, according to the conditions of soil, food, and climate which he enjoys. It is thus that we have the Arabian, Tatar, Ukraine, Shetland, and other stocks, each differing so widely from the others, that the merest novice could not possibly confound them. Besides these primitive stocks, a thousand *breeds*, as they are called, have been produced by domestication, so that at the present time it would require volumes even for their enumeration. In our own country, for example, we have such breeds as the Flanders, Norman, Cleveland, Suffolk, Galloway, Clydesdale, and Shetland; and of these numerous varieties, more especially adapted for the turf, the road, the cart, or the carriage. All this exhibits the wonderful docility of the horse, and proves how admirably he is adapted to be the companion and assistant of man, as the latter spreads himself over the tenantable regions of the globe. It is to the character, training, and management of the horse thus domesticated that we devote the following pages.

DOMESTICATED VARIETIES.

Horses exist, as we have said, in numerous varieties, distinguishable by size, strength, colour, and other qualifications, the result, most likely, of peculiarities of climate, food, and artificial treatment. The following is a brief notice of the leading varieties or breeds now common in Britain:

The Arabian.

The Arabian horse is considered to occupy the highest rank among the numerous cultivated varieties, and embodies that qualification in its purest condition, known by the term *thorough-bred*. The pure Arabians are somewhat smaller than our race-horses, seldom exceeding fourteen hands two inches in height. Their heads are very beautiful, clean, and wide between the jaws; the forehead is broad and square; the face flat; the muzzle short and fine; the eyes prominent and brilliant; the ears small and handsome; the nostrils large and open; the skin of the head thin, through which may be distinctly traced the whole veins of the head. The body may, as a whole, be considered too light, and the breast rather narrow; but behind the arms, the chest generally swells out greatly, leaving ample room for the lungs to play. The shoulder is superior to that of any other breed; the scapulæ, or shoulder-blades, incline backwards, nearly in an angle of 45°; the withers are high and arched; the neck beautifully curved, and the mane and tail long, thin, and flowing; the legs are fine, thin, and wiry, with the pasterns placed somewhat oblique, which has led some to suppose that the strength was thereby lessened, which is by no means the case; the bone is of uncommon density, and the prominent muscles of the forearm and thigh prove that the Arabian is fully equal to all that has been said of his physical powers.



English Hunter—Arabian—Shetland Pony.

The Arabs of the Desert have made the breeding of horses their sole occupation for ages bygone; and from their strict attention to certain rules, they may be justly regarded as the first breeders in the world. They take infinite trouble in grooming their steeds, and are extremely regular in their hours of feeding them morning and evening. They get but little drink, and that is supplied to them two or three times a day; they conceive that much water not only destroys their shape, but also affects their breathing. In spring, they are pastured on dry aromatic herbage; and during the rest of the year they are fed on barley, with a small quantity of straw; and they are the hardiest horses in the world. The Arab trains his horse by kindness, and never on any occasion strikes it; the consequence is, that the animal shews a degree of affection and tractability in which most British horses are quite deficient. The pure Arab horse is employed only for riding, and possesses great fleetness.

The following interesting account of the hardihood of the Arabian is given by M. Chateaubriand, in his travels in Greece: 'They are never put under shelter, but left exposed to the most intense heat of the sun, tied by all four legs to stakes driven in the ground, so that they cannot stir. The saddle is now taken from their backs. They frequently drink but once, and have only one feed of barley in twenty-four hours. This rigid treatment, so far from wearing them out, gives them sobriety and speed. I have often admired an Arabian steed thus tied down to the burning sands, his hair loosely flowing, his head bowed between his legs, to find a little shade, and stealing with his wild eye an oblique glance of his master. Release his legs from the shackles, spring upon his back, and he will "paw in the valley, he will rejoice in his strength, he will swallow the ground in the fierceness of his rage;" and you recognise the original picture as drawn by Job.'

The Arabs are exceedingly particular regarding the pedigree of their horses; and they have amongst them a breed which they declare has descended from a horse of King Solomon. It must not, however, be supposed that all the horses of that country are of the finer kinds; for the Arabs have three distinct breeds; the two inferior kinds, they allege, were introduced from India and Greece. The superior kinds they call nobles; and they are never sold without a pedigree, which is most scrupulously attended to.

The British Racer.

The British race-horse is a cultivated breed, originally sprung from the Arabian, and to which is traced the quality of being *thorough-bred*. The skins of race-horses

are delicate, with short hair, usually tending to the bright-brown or bay generally characteristic of the horses of the East, and sometimes to the gray, prevalent likewise among the Arabs and Barbs. They are frequently chestnut, which may be looked upon as a mixture of the dun or tan colour of some of the races of Northern Europe with the finer brown or bay; and sometimes, though very rarely, they are of the bright-black common to the great horses of the plains of Germany. They are of medium height, rarely exceeding fifteen hands. Their form is that which an almost exclusive attention to the property of speed has tended to produce. They have the broad forehead, the brilliant eyes, the delicate muzzle, the expanded nostrils, and the wide throat, characteristic of their Eastern progenitors. Their light body is comparatively long, and suited to the extended stride. Their chest is deep, so as to give due space to the lungs, but comparatively narrow, preventing the fore extremities from being overloaded, and the limbs from being thrown too far asunder in the gallop. Their shoulder is oblique, to give freedom of motion to the humerus; and their haunch is long and deep, beyond that of any other known race of horses, indicating the length of those bones of the hinder extremities on which the power of progression essentially depends. Their limbs are long and muscular to the knee and hock, and below, tendinous and delicate; and their pasterns being long and oblique, give elasticity to the limbs.

The pedigree of race-horses is always a matter of consequence to the breeder and purchaser of these animals, and is preserved with the same degree of care as the genealogy of many a noble family. By jockeys and others, therefore, a list or stud-book is kept of the sires and dams of their horses, which can be exhibited if required. The pedigree of many fine racers of the present day is traced through stud-books to the Darley Arabian—a horse purchased by a Mr Darley at Aleppo, from which it was imported to England. One of its immediate descendants was the celebrated Flying Childers, bred by Mr Childers of Carr House. This beautiful racer is reputed to have been the fleetest runner ever known in England, or perhaps in the world. On one occasion he ran (carrying nine stones two pounds) round the course at Newmarket—which measures three miles, six furlongs, and ninety-three yards—in six minutes and forty seconds.

Horse-racing is essentially an English sport, with its head-quarters at Newmarket, Epsom, and Doncaster. Many object to it as cruelly taxing the strength of a noble animal; but when the distances to be run are not too great, and where steeple-chasing is prohibited, the race becomes a legitimate test of fleetness, courage, and endurance. An animal that has repeatedly beaten a host of competitors, must possess superior qualities, rendering him of the utmost value for breeding purposes—and these qualities, especially we repeat of speed, spirit, and endurance, are, we believe, best brought out by racing, judiciously and humanely regulated. Unfortunately the sport is too often mixed up with dissipation, fraud, and gambling.

Hunters, Coach-horses, Hackneys.

The hunter is a combination of the thorough-bred race-horse and half-bred horses of greater strength and bone; but changes are continually taking place in its character. The older race of hunters has been giving place to one of lighter form and higher breeding, and even the thorough-bred horse is now employed by numerous sportsmen. In his improved state, the hunter may rank as a saddle-horse of the first class, combining strength with fleetness. The prime qualities of a hunter may be briefly summed up—head small, neck thin, crest firm and arched, a light mouth, broad chest, body short and compact, the hocks well bent, power behind to push him over difficulties, and broad well-made feet turned outward. He is prepared for his duties by physic, air, and exercise. To do him justice, the hunter should not work above three days a week; and after a hard day's run, he ought certainly to have two or three days of rest. The charger or cavalry-horse partakes of the qualities of the hunter—great strength and spirit, without which he would be unable to endure the toil of warfare in a rough country.

The better kind of coach-horses owe their origin to the Cleveland bay, and are principally bred in Yorkshire, Durham, and the southern districts of Northumberland; and some few have been produced in Lincolnshire. The coach-horse is produced by a cross of the Cleveland mare with a three-fourth or thorough-bred horse, which is possessed of sufficient substance and height. The produce of these is the coach-horse of the highest repute, and most likely to possess good action. His points are advantageously placed, with a deep and well-proportioned body, strong and clean bone under the knee, and his feet open, sound, and tough. He possesses a fine knee-action, lifts his feet high, which gives an elegance to his paces and action: he carries his head well, and has a fine elevated crest. The full-sized coach-horse is, in fact, only an overgrown hunter, too large for that sport. Before the days of railways, the carriage-horse, reduced to drawing stage-coaches, was often used in a very disgraceful manner. Urged with a heavy draught to the height of his speed, almost incessantly wrought, whipped unmercifully, and poorly groomed, his fate was melancholy in the extreme. It ought to be recollected, that in proportion as the load or draught is increased, so is the animal's power of speed lessened; and therefore to make him both draw a heavy weight and run also, is to put him beyond his natural powers, and his muscular energy suffers accordingly. We shall afterwards advert to the principles which ought to regulate both draught and speed.

The term *Hackney*, in common use, is employed to denote a kind of horse fitted for general services, and is therefore understood to exclude the horses of the highest breeding, as the thorough-bred horse and hunter; and there is further associated with the idea of a hackney, an animal of moderate size, not exceeding fifteen hands, and possessing action, strength, and temper. Our present breed of hackneys have a considerable portion of racing blood in them, varying from a half to seven-eighths. The latter are too highly bred for the general purpose of a roadster, as their legs and feet are rather tender; and their long paces and straight-kneed action are ill adapted for the road, being more fitted for cantering and running than the trot, which is the distinguishing characteristic of a good hackney. Indeed, they should never be permitted to go at any other pace than a trot, which is undoubtedly much better adapted for the road than cantering.

Nothing is more essential in a hackney than sound strong fore-legs, and also well-formed hind ones; his feet must be quite sound, and free from corns, to which hard-ridden horses are very liable; and he ought only to lift his fore-legs moderately high. Some are of opinion that he cannot lift them too high, and conceive, while he is possessed of this quality, he never will come down. There is a medium, however, in this, as a horse that raises his fore-legs too high in trotting is always disagreeable in his action, which greatly shakes and fatigues the rider; besides, he batters his hoofs to pieces in a few years. The principal thing to be attended to is the manner in which the hackney puts his feet to the ground; for if his toes first touch the road, he is sure to be a stumbler. The foot should come flat down on the whole sole at once, otherwise the horse is not to be depended upon in his trotting. A hackney should be particularly even-tempered, and not given to starting. The thorough-bred hackney ought to possess two qualities, indispensable to the safety of the rider—he should never shy at anything on

the road, and his motion at a trot should be much more smooth than that of a half-bred horse.

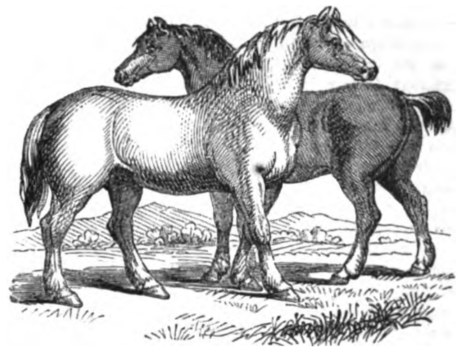
The proper kind of saddle-horse is only a variety of the hunter, possessing less or more breeding, according to the nature of the work required of him, and the taste of the breeder. Of the great varieties of saddle-horses, there may be said to be a chain of connection, as respects spirit and form, from the racer to the cart-horse; and therefore the station which any individual occupies is almost undefinable. The saddle-horses of England are celebrated for their beauty and action; and nowhere are seen so many of elegant forms as in London. Latterly, the breeds have been tending to greater lightness, the state of the roads not now requiring the weight and substance which was at one time necessary.

The Cart or Draught Horse.

The cart-horses of Great Britain are extremely variable in point of size as well as in shape, differing in almost every county. One principal character, however, is weight, to give more physical force in the draught. They should not be above sixteen hands high, with a light well-shaped head and neck, short pointed ears, with brisk sparkling eyes; their chests should be full and deep, with large and strong shoulders, well-raised withers, and deep wide chest. The back should be straight, and rather short, the ribs well arched, and the space between the last rib and the haunch-bone short. A long-carcassed, flat-ribbed horse tires easily, eats voraciously, and thrives badly. The limbs, strong, flat, and muscular, and well placed under the body, should not be disfigured by too much hair—a very common fault in the heavier English horses. The joints should be large and pliant, the feet wide, tough, and sound; and with limbs and feet such as these, the cart-horse will be able to walk easily four miles an hour, or plough his acre daily. For ordinary farm-work, we prefer strong-boned, clean-limbed horses with some breeding, and with the activity and courage which accompanies breeding, to the coarser, heavier, more sluggish race still too prevalent.

In the midland counties of England—Warwickshire, Derbyshire, Leicestershire, Lincolnshire, and Nottinghamshire—there is a very large breed, called the great cart-horse. It was bred in the lowland rich alluvial pastures of the plains of these counties, from the Flemish and Dutch horses with the larger English breed. Mr Bakewell introduced horses, and also mares, from the Netherlands, and thus produced those fine animals with Belgic blood both on the side of the sire and dam. The very large horses of seventeen hands and upwards are only useful for the purposes of brewers' drays, wagons, and the slop-carts of London. It is, however, doubted if they answer the better for their gigantic size; and all who have written on the subject, consider that they are inferior in point of strength, on account of their bulk; for by the feeding which is required to increase their dimensions, little of muscular fibre is produced, the growth being principally in the cellular tissue and fat; and the additional quantity of food required to keep up their system, must more than counterbalance any advantage to be reaped from their size.

Latterly, considerable pains have been taken to improve the qualities of ordinary cart-horses, among which we include those required in agriculture. A breed called the Clydesdale is highly valued for either cart or plough. Animals of the Clydesdale breed reach to a large size, and are not unfrequently to be met with sixteen and a half hands high. These animals are strong and hardy, but their heads are somewhat coarse, and they are rather flat on the hinder quarters. The usual colour of these horses is gray or brown. This breed is supposed to have originated about one hundred and forty years ago, between the common Scotch mare and the Flanders horse. As a breed, the Clydesdale is rapidly rising in estimation, and is now extensively used.



Clydesdale Horse—Suffolk Punch.

Ponies.

A horse beneath thirteen hands is called a pony, but this definition is not very strictly attended to, and the same thing may be said of the *galloway*. The old Scottish galloways, which took their name from the district of Galloway, in the south-western extremity of the country, are now nearly extinct. They were stout, compact animals, sure-footed, and of great endurance, and on these accounts invaluable in travelling over rugged and mountainous districts. The beauty and speed of the galloway were supposed to have arisen from the breed having been the produce of the Spanish jennets that escaped from the wreck of the Spanish armada; and these, crossed with our Scottish horses, gave rise to this esteemed breed. But we apprehend they were famous at a date long prior to that event, as this district is known to have supplied Edward I. with great numbers of horses. This breed seldom exceeded fourteen hands in height: their colour was generally bright bay or brown, with black legs, small head and neck, and their legs peculiarly deep and clean. A compact, stout-built pony, of from thirteen to fourteen hands high, and possessing some of the qualifications of the galloway, is called a *cob*, which is valuable as a steady pacer, at an easy rate.

The small ponies of the Highlands of Scotland and Shetland (usually called *shelties*) may almost be termed wild animals; for they go at large in herds on the hills and wastes, and are not shod till caught and put into training. They are docile and tractable, and being very sure-footed, are the best adapted for boys' riding. The Welsh pony is more handsomely formed than that of Shetland; has a small head, high withers, deep round body, and excellent feet. The Exmoor and Dartmoor ponies are also a hardy sure-footed race, well adapted for riding in wild districts. The ponies of Norway and Sweden, which are of a dingy cream colour, and of which there are now occasional importations to Britain, are considerably larger than the Shetland or Welsh breeds, and are hardy, sure-footed, and docile.

REARING OF HORSES.

The breeding and rearing of horses are carried on professionally in England, chiefly in Yorkshire; but many private gentlemen and farmers also address themselves to it as a means of pecuniary profit and the improvement of their animal stock. We do not pretend here to offer any specific directions on this branch of our subject, it being one in which the public at large are not particularly interested; and a few observations seem all that is necessary.

The circumstance which the breeder of horses requires to keep most in mind is, that the qualities, good or bad, of the animal are hereditary. Finely made horses

produce finely made descendants, and *vice versâ:* heavy cart-horses never produce animals possessing the qualities of racers. Thus the bone, blood, and general make are directly transmissible; and, in the case of crossing, the produce is found to possess a proportional share of both sire and dam. Cross-breeding between extremely different horses is not found advantageous: it is a generally recognised principle, that the nearer the resemblance between the parents, so will the produce be more satisfactory. Mr Smith, in his *Observations on Breeding for the Turf*, remarks, that 'the stock of some mares will frequently partake most of the dam, and that of others, most of the sire; and sometimes one foal will partake most of the mare, and the next perhaps, most of the horse, &c. It also occasionally happens that the produce bears some resemblance to its grandsire, grandam, or other distant kindred; and although this does not perhaps often occur, so as to be very perceptible, yet as their qualities must, in a lesser or greater degree, descend to their progeny, it has always had its due weight; hence the value and partiality to blood, or ancestral excellences, transmitted through many generations.' He further observes, however, 'that he is disposed to attribute more in general to the dam than to the sire, inasmuch as he is decidedly of opinion that a good mare put to the worst thorough-bred horse would be much more likely to produce a runner, than a bad mare put to the most fashionable stallion in England; and therefore a person possessing good mares may bring any stallion into repute.' The grand aim of the breeder must be the propagating of excellences, and avoiding defects; but this is not to be accomplished, as respects important alterations, all at once; improvements in this, as in everything else, being the work of time and a judicious experience. Breeding *in-and-in*, as it is called, or between close relationships, is decidedly pernicious, and should by all means be avoided.

The season for mares is about February and March, but in some cases it continues later; and the term of gestation is generally over eleven months. The foal remains with the mother till weaned, which takes place earlier or later, according to the quantity of milk, the strength of the animals, and the season of the year. On removal, it requires to be carefully attended to, and provided with soft nourishing diet. Few things contribute more to the health and perfection of young horses than a sweet, sound, and hard-bottomed pasture-range.

The operation of cutting is seldom performed on thorough-bred colts, but with all others it is common. It is an operation which ought by all means to be left to the veterinary surgeon or skilful farrier. The best authorities recommend it to take place with young cart-horses when four or five months old, but if for carriage or light work, it may very properly be postponed till the animal is twelve months old. The use of the operation is to render the horse more submissive than if left in an entire state, and to devote him altogether to the work he is required to perform. The advantages, whatever they are, are in some measure lessened by the lowering of spirit. The practice, however, is universally recognised in Britain, as one indispensable where numbers of horses are congregated, and required to be kept in good condition.

Breaking, or reducing the young animal to obedience, is a most important point in the education of the horse. If previously accustomed to handling, the difficulty of breaking will be much lessened. Racing-colts are now begun to be broken at one year old, and saddle-colts at two years, and are finally and fully broken and trained, some at three, and few later than four years old. Breaking horses is a regular business, and is best left to the person who is well accustomed to it, provided he follow a judicious course of treatment. As in the training of children, gentleness, with firmness, ought to be a prevailing principle of management. The chief apparatus of breaking is a powerful bridle or head-tackle, with boots or pads strapped on the legs, to prevent them knocking against each other. The young horse is to a certain extent trained before his back is mounted; all the preliminary part of the process of subduing being accomplished while he is led by the bitted tackle. His back is not to be mounted till he is evidently able to endure the load without injury to his figure: too early mounting is apt to make him hollow-backed for life. In putting on a saddle for the first time, great caution should be taken; let the girths be drawn loosely, the crupper smooth, and keep the stirrups from dangling. In short, the animal requires on this trying occasion to be treated with as much kindness as it is possible to employ.

Having, by the various means which are adopted, brought the animal into subjection, and in effect taught him that he must in future act the part of a dutiful servant to an indulgent but firm master, the next step is to teach him his paces. These are partly artificial. Commence with slow and regular walking; whenever he is inclined to bolt, bringing him back to the steady pace you desire. After he has been accustomed to slow paces on a methodic plan, go on to the slow trot, then the quick trot, and, lastly, the canter and gallop. By no means allow him to mix these paces—that is, half-canter and half-trot—which would be an ungainly hobble; but let him know that he must, for the time being, keep to one kind of pace. The skill of the breaker consists in enforcing these lessons, and teaching the animal to change readily and neatly from one pace to another by little more intimation than a twitch of the rein. Lawrence recommends that 'a graceful canter should be encouraged, commencing with the proper or off-leg foremost, and the nag accustomed to be pulled up from the canter to the trot without unseemly and unpleasant blundering. The lessons should not be too long or fatiguing, but the young animal kept in as cheerful and easy a state as possible.' The first shoeing ought to be performed with great care, so as to alarm the animal as little as possible.

In connection with the breeding of horses, we may say a few words respecting *mules*, or the hybrid offspring of the horse and ass. The mule proper is the produce of a male ass and mare; when the parents are the horse and she-ass, the produce is called a *hinny*. The mule is the superior animal, partaking to a larger degree in the qualities of the horse; it is more robust, plump, and hardy, and better adapted for all the ordinary purposes of riding and draught. The hinny is more thinly made, has a longer head, and is altogether more like the ass than the horse. Mules of both kinds live to a very old age, and when properly trained, they are tractable, and very serviceable animals. There are comparatively few mules in Britain; but in Spain, and some other countries of Southern Europe, also in Spanish America, they are numerous, and are used in carriages of people of the highest rank. According to a well-known principle in natural economy, by which intermixture of kindred species is not allowed to go beyond a single step, and only for one generation, mules do not usually breed; and the stock requires to be kept up by a recurrence to the common parentage.

The Teeth—Age.

The horse attains maturity at five years old, and he is in his prime till eight or nine. If no unfair play be used, his age may be judged of from his teeth, or, as it is called, *mark of mouth*. At five years old, when the teeth have been fully developed, the horse possesses six teeth in the front of each jaw, called the incisors or *nippers;* it is with these teeth that he bites. At a short distance from each end of the row of incisors, and in each jaw, there is a solitary canine tooth; these canine teeth are technically named *tushes*. At a greater

distance inward in each jaw, and on each side, there are six grinders—the whole apparatus being designed to bite or crop the herbage, to tear, and to chew. At five and a half years old, the nippers are marked by a natural cavity formed in the substance between the outer and inner walls, and it is the presence or absence of these darkish marks that certifies the age of the animal. When the horse reaches six years, the marks in the two front nippers in the nether jaw are filled up, and the tushes are blunted. At seven years, the two nippers next the middle ones are also filled up; at eight, the two outer ones are filled up also, and the tushes are round and shortened. The lower nipper teeth are now all smooth; the marks are gone; but in the teeth of the upper jaw, marks remain a year or two longer. At eight years, the disgraceful practice of *bishoping*—a term given from the name of the inventor—is often resorted to, for the purpose of imitating the obliterated marks. An engraving tool is employed to cut the surface, and a hot iron is then applied to give a permanent dark stain. This infamous trick may impose on the ignorant; but a person skilled in horses can easily detect the imposition, from the stains being diffused around the marks, which, moreover, are round instead of oval.

As a horse, if well treated, remains in excellent working condition till twelve years, and even later, the disappearance of the marks on the teeth is often of little consequence. Some horses are as valuable to their owners at fifteen years as they are at eight; and for ordinary saddle-work, ten to twelve may be considered an age sufficiently young. It is important, however, that the teeth are capable of mastication; for if the animal is unable to chew his food properly, he cannot be kept in good condition, or fit for the performance of his duties. In consequence of the very general abuse of horses, few live till twenty-five years old; and the instances of any living till above thirty are rare.

Technical Terms.

Horsemen employ terms to horses which are not strictly adhered to in ordinary language. A male horse left uncut is said to be an *entire horse*, to distinguish it from the *gelding* or cut animal. A female horse is always spoken of as a *mare*. A young male horse is called a *colt*, and a young female, a *filly*. *Thorough-bred*, as already noticed, is applied only to animals whose pedigree can be traced to an Arabian origin, without stain or any common intermixture. When the pedigree of the racer is to a certain degree stained, the animal is called a *cocktail*. The term *blood* is of more loose signification; but what is generally understood by it is a horse which is thorough-bred, or of the blood of the Arabian, and consequently shews a fine spirit and action. A horse may be half-bred, three parts bred, and so on, according to his pedigree. The half-bred is produced from a racer and a common mare. Some of the best riding-horses are of this stamp. The term *welter horse* is applied to racers which are able to carry the highest weight.

Horses are measured by *hands*, four inches being reckoned to the hand; the measure is taken from the highest point of the withers to the ground. To all the more prominent parts of the body and members, certain technical names are applied; for example, to take the four extremities first: the *muzzle* includes the lips, mouth, and nostrils; the *withers* are the sharp protuberance over the shoulders between the back and neck; the breast is the *counter;* the *arm* is the upper part of the fore-leg, but enveloped in the muscle of the shoulder; beneath it is the *forearm*, which is the higher part of the visible leg, and extends downward to the *knee;* below the knee we have another stretch called the *shank*, which extends to the *pastern*, or, as we might call it, the ankle; the *fetlock* is behind the pastern; beneath are the feet. A few of the hinder extremities are named as follows: the *croup*, which extends from the loins to the root of the tail or rump; the *flank*, extending from the ribs to the haunches; and the *leg* or thigh, which reaches down to the *hock* or middle joint of the hind-leg, corresponding to the knee in the fore-leg. The left side of a horse is called his *near* side; and his right, the *off* side.

The greater number of British horses are of a dark colour, inclining to black or brown, but of innumerable shades. One kind of brown is called bay, and another the chestnut; a yellowish chestnut is termed the sorrel. The roan is a blending of red and whitish tones. The gray is a mixture of white and black hairs, and in old age, becomes altogether white. The dark colours are the most esteemed for their physical qualities, and patches of white on the legs are considered defects or foul markings.

STABLE MANAGEMENT.

The horse, as has been already mentioned, possesses very delicate senses, and is nice in his habits, in which respect he differs very materially from black-cattle. In a state of nature, the animal seems to be best adapted for a mild and genial climate, and to rejoice in freedom and space. When reduced to domestication, care should be taken to violate as little as possible his natural tastes and habits. His delicacy of constitution, augmented in no small degree by an artificial mode of life, should warrant the best attentions of his keepers; and whatever be the nature of his work, he should be treated with kindness, regularly fed and supplied with pure water, allowed a cleanly and well-ventilated habitation, and his body and limbs preserved free from dirt and all offensive matter that may cling to them. The leading features of management may be defined as follows:

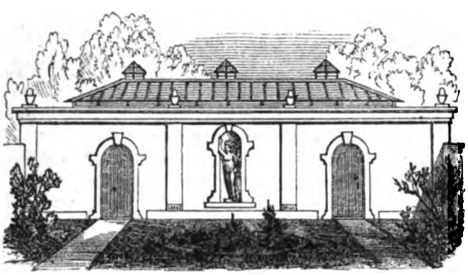
The Stable.

A high authority states it as his belief that nine-tenths of the diseases which afflict horses owe their origin to, or are greatly aggravated by, the defective arrangement and construction of stables. The chief points to be attended to are: the situation of the stable; its construction, so as to prevent damp and secure ventilation; its size; and its fittings and appendages. A stable should never be built in a marshy or hollow spot, but on a gentle declivity, so as to admit of good drainage, and with a southern exposure, in order to command good light—another important point. The first thing in the actual construction is how to secure dryness. The effects of damp on horses are immediately visible in languor, refusal of food, liability to colds and inflammation. Glanders and farcy, if not entirely owing to a humid atmosphere, as some hold, are certainly encouraged and fostered by it. The site of the stable, then, must be surrounded and intersected by smaller drains leading into a main-drain, with a good outfall. The walls again, whether of stones or brick, should be made *double*—the hollow space, in order to prevent the lodgment of rats, being not more than two inches wide. To provide against surface-water rising up the walls by capillary attraction, the first course above the ground may be covered with a coating of coal-tar and sand, or with sheet-lead. The roof should have a range of guttering completely round it, and the rain-water should be collected in a tank for use.

Damp *floors* are in so far provided against by thorough under-drainage; but a floor completely impervious to moisture from below may be had by constructing it of asphalt, or of flags set in cement, and with grooved surfaces. Good floors are also made of bricks set on edge, or of tiles with corrugated surfaces. To prevent the lodgment of the urine of the animals, the floors of the stalls should slope two or three inches in ten feet towards a channel running along behind the horses, which channel should itself have a slope towards the grating or gratings of the drain connected with the liquid-manure tank. These drains should be carefully

trapped. The slope of the stalls has no injurious or incommoding effects on the horse while reclining, as some have imagined. A dry stable-floor is effectually secured by the use of Forbes's drain-pavement, in which the flooring-bricks are grooved so as to form a system of channels for the urine.

The inside of the stalls should be boarded, and a lining of wood, four or five feet in depth, should be carried round the bottom of the other walls; all above should be plastered and white-washed.

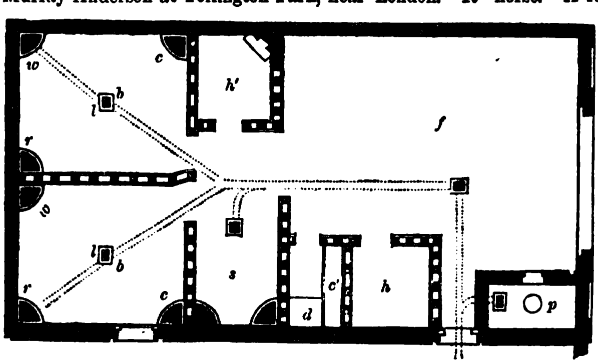


Elevation.

The evils of defective ventilation to animal life in general (see PRESERVATION OF HEALTH, also WARMING AND VENTILATION) are aggravated in the case of horses by the quantity of ammonia developed from the urine. This is less the case in stables where the floors are kept dry and sweet by the means above described; still, in every stable, means must be provided for the constant removal of tainted air, and the supply of fresh. The principles laid down in the number just referred to will be found applicable here.

A stable should never be large, as it is then liable to great fluctuations of temperature, according to the varying numbers in it at one time. A good size is one with ample room for six or eight horses. A stable with a row of stalls on one side only is better than one with double rows; if double, the space between should not be less than eight or ten feet. Sixteen feet is a proper width for a stable with a single row, ten feet being allowed for the depth of the stalls. Each stall is usually five and a half feet wide, but when space will permit, a width of six feet is advisable.

We give a ground-plan and elevation of what is considered by good judges a model stable, erected by Mr Murray Anderson at Tollington Park, near London. It



Ground-plan.

is planned to accommodate three horses, and contains coach-house and stable-yard under the same roof: *lb*, *lb* are two loose boxes, having each a rack for hay, *r*, a corn-box, *c*, and a water-trough, *w*; *s* is a stall five feet six by nine feet; *c'* is a corn-bin, and *d*, one for beans; *h* is a hay-shed; *h'*, the harness-room; *f*, the covered yard for cleaning carriages, &c.; *p*, the dung-pit, which is an air-tight tank, with a ventilating tube rising above the roof. The dung is thrown down by a trap-door inside, and removed by another outside. The building is lighted from the roof, which also contains three ventilators for the escape of the air. Fresh air is admitted by gratings at the bottom of the pillars represented in elevation; these being hollow, the air ascends, and enters the stable by similar gratings at the top inside. The whole structure, walls and floor, rests on concrete.

We have now to consider the fittings; and first as to *windows*. When we say that the stable should be well lighted, we certainly oppose one of the most vulgar prejudices respecting horse-management. In most instances, stables are kept as dark as dungeons, greatly to the injury and discomfort of the inmates. It is impossible to understand what can be rationally designed by keeping horses standing in the dark during their waking-hours. Nature never intended anything of the kind, and the practice should be abolished. The best way of lighting is from the roof, the windows being capable of being easily opened from below by means of cords and pulleys; which arrangement furnishes at the same time a means of ventilation. When lighted from the side-walls, Mr Stephens recommends the lower part of the window to be *dead*, the upper part only glazed, and capable of being opened. The stable should be entered by one door only, placed at the end of the building; it should be eight and a half feet high, and not less than five wide. It is advisable to have a spring by which it can be kept open until the horse is clear; when this is released, the door should be so hung as to close itself.

Hayloft—Racks—Mangers.

The hayloft, or place of deposit for hay, ought not, as is usually the case, to be over the stable, but adjacent; and a chamber level with the floor of the stable, and behind the stalls, is preferable, the hay being passed into the racks through doors opening from this chamber. In cases where haylofts are used, let them be kept as clean as possible, and allow no opening to the racks.

Hay-racks of the best material and form are made of iron, the bars rounded, and two inches from each other. The rack need not traverse the whole breadth of the stall, because in such a plan rubbish collects in the corners. A size to hold from a half to a whole stone of hay will be sufficient in most instances. A convenient form is that of a convex or bulged grating from the wall, placed a little above the head of the horse. A rack of this or any other shape cannot be kept too clean; the bars should be daily rubbed, and all refuse of hay removed. In improved racks, a drawer is provided, into which the *seeds* drop. A very ingenious and economical form has recently been introduced. It consists of a square iron casing, placed in the corner of the stall, the upper end being formed by a wide grating; a movable bottom slides up and down in the casing, being drawn up towards the top by a weight, which is sufficiently heavy to lift also the hay which is placed upon it. As the horse draws the hay through the top grating, the weight keeps it constantly pressed against it, so that he withdraws only a mouthful at a time, and is prevented from littering it about his stall. Mangers, for the supply of corn, &c., are now almost universally made of iron, with enamelled interiors; they are thus easily kept clean. They should be supplied through a spout regulated from the outside of the stall. Water is also provided now by an iron enamelled trough, to which it is supplied by a special water-pipe and tap, and withdrawn by means of a plug in the bottom leading to a waste-pipe.

Bedding—Cleaning.

The good horse sleeps in a lying posture, his legs being partly drawn under him, and his head remaining up. A horse that habitually sleeps standing, or will not lie down at night, is usually reckoned to be of little value; for it is indispensable to doing his duty during the day that he rests well at night. The preparation of a bed for the animal ought to be one of the most pleasing parts of a stable-keeper's duty, and he should perform it well. The best bed is made of wheat-straw; but when that is dear, or cannot be got, the straw of oats may suit the purpose. The more even and less rumpled the litter, the better. The bed should be made level, or sloping slightly from the sides and head towards the centre, and be completely free of hard lumps. All ought to be smooth, clean, soft, and the depth of litter perhaps seven or eight inches. Every morning, the soiled litter is to be taken away to the dung-yard, and the clean portion separated and placed at the head of the stall, or in some other convenient situation, ready to be employed again at night. The stable should be clean swept, brushed, and thoroughly ventilated every morning, leaving impurities neither on the ground nor in the atmosphere.

Stable Furniture—Stablemen.

Every stable is to be provided with proper receptacles for hay and straw. The oats, peas, beans, bran, &c., should be kept in one large chest with divisions, or separate chests, and, if possible, be placed in an apartment separate from the stable. For small stables, an adjoining room should be fitted up neatly for the accommodation of the corn-chest, the saddles, and other apparatus; all saddles, bridles, and small articles being properly hung on hooks on the wall, or placed on other appropriate supports. A cupboard for combs, brushes, &c., will be an advantage. If the stable be not supplied with water in pipes, a well should be at hand.

Horses require to be under the charge of persons who understand the business of attending to them in all their varied wants. Some individuals seem to imagine that any boy or lad will do for taking care of a horse. This is both inhumane and bad policy. Where only one horse is kept, a steady lad, under the directions of his master, and instructed in the line of his duty, will often be found sufficient; but he requires constant looking after, for all young persons, and some old ones too, are disposed to play pranks with horses, and rob them of their food. The ordinary class of ostlers are not regularly instructed in the qualities and wants of the horse. All they know is empirical, and their prejudices are frequently absurd. Let all such persons, therefore, be estimated at their proper value; and on committing your horse to any of them at an inn, see that he does his duty to the animal, both as respects cleaning and feeding.

In stables in which two or more horses are kept, a regular groom should be employed; and this person should reside close by the stable, so as to be always at hand. The qualifications of a groom ought to be steadiness of conduct, promptitude in a case of difficulty, openness to advice or instructions, experience in well-managed stables, taste for cleanliness; and he should be as desirous of making his charge comfortable as he would his own person.

If all horses were good-tempered, or rendered docile by kind treatment, they might be advantageously left at liberty in their stalls; circumstances, however, require that they should be restrained; but this should be done with as little pain to them as possible. The halter or rein from the headgear should be led to a ring at the head of the stall, leaving the animal at liberty to lie down in an easy posture. The rein, whether of rope or chain, should not be tied to the ring. It should go through the ring, and drop down with a plummet at the extremity to keep it down, yet allowing the animal to pull it up or allow it to sink at pleasure. A shorter halter may be employed during the day than at night, so as to keep him from straggling backwards into the passage or gangway. Some horses are most restive in restraint, and commit tricks to loosen themselves; and others, by awkwardness of movement, get the halter round their feet, and are thrown down, and occasionally, if assistance be not promptly rendered, are much injured in their struggles to regain their feet. A soft level bed and abundance of room are the best preventives for this kind of accident.

Grooming—Dressing—Trimming.

The skins of horses are liable to become clogged with a scurf of dried perspiration, along with particles of dust and mud, which collect and lodge among the hairs. It is of great importance to remove these impurities by currying and brushing, for the sake of the health of the animal, independently of the value of the operation as respects the appearance of his coat. The degree to which this species of grooming is carried will of course very much depend on circumstances; but, as a general rule, it should take place every morning before the horse is led forth to the labour of the day.

The grooming is commenced while the animal is in his stall—his wrapping-cloth, if he have one, being removed, and the restraining-rein being lengthened, to allow his standing a little back into the gangway. If restive, his head must be tied up. All refuse having been previously removed, a little of his bedding may be drawn out for his hind-feet to stand upon. The first thing done is to curry him with a curry-comb—a flat iron instrument, with rows of short blunted teeth and a handle. By being drawn along the surface of the body and limbs, it rakes up the lumps of hair, and generally loosens and brings up all extraneous substances. The groom commences with the neck and shoulders; next he goes to the body, hinder quarters, belly, and legs, both sides being treated alike. The curry-comb must not in any case be used roughly, and with thin-skinned horses its application must be very gentle. If the horse be regularly groomed, and its work not dirty, a gentle scrubbing with the curry-comb will in most cases suffice. In performing the operation, a brush may be held in the other hand, with which to clear out the teeth when necessary. After the curry-comb has gone its rounds, apply the brush in turn, going over the whole surface with it, from head to heels, to remove all raised impurities, and to lay the coat smooth. A rough hair-glove has been introduced into use as an improvement upon the brush; and it certainly possesses the advantage of being more easily applied to the head, limbs, and flank, than the brush. Should the horse be changing his coat, which he does twice a year, the curry-comb must not be used at all—a rubbing with a straw-wisp being perhaps sufficient.

After the currying and brushing, the groom proceeds to comb the forelock, mane, and tail, so as to make all the hairs lie straight. This finishes the grooming; but if the legs or feet be white, they will perhaps require washing with warm water and soap—to prevent the growth of a yellow appearance—and then dried with a wisp. We have only to add, that if horses are not groomed regularly in this manner, they will inevitably lose their health, or be troubled with parasitical animals lodging beneath the hairs, and never have a glossy and cheerful appearance. Some horses have a great repugnance to being groomed, but this generally arises from harsh treatment while they were young: if treated considerately, they will feel pleased with the friction, and grateful for the attention bestowed on them.

The cleaning of a horse after work is as necessary as the morning grooming. When a horse is brought to the stable in a state of perspiration, it should not be taken in to be at rest all at once, but be walked gently about.

till it becomes moderately cool. This allows the excitement of the blood-vessels and muscles to be allayed gradually, and prevents any sudden stoppage of the pores of the skin. To assist in drying and cooling down the animal, he may be scraped or rubbed with wisps. Wisping is preferable. After the horse has been walked and wisped, his legs and feet should be washed with water and a brush or sponge, and also his belly, if it be dirty with sparks of mud; but, after any such washing, every part should be thoroughly dried with a fresh wisp. Never leave a horse with wet legs or feet. In the country, it is not unusual to walk horses into a river to wash their legs—a practice most detrimental to their health, and which should not be allowed.

When the horse has been cleaned and dried, the cloth may be thrown over him, and he may be tied to his stall. The cloth used in summer should be lighter than that used for winter. It is customary for grooms to exercise horses with the stable-cloths wrapped round them, and then perhaps the next hour they are taken out saddled, and without any cloth at all. This seems an inconsistency. The use of cloths is to protect the animal's loins from cold, and is unnecessary in fine weather. If the horse has to stand still out of doors, and the weather be ungenial, his loins ought by all means to be protected by an oiled cloth. The horse is very susceptible of injury by exposure of the loins; and it will be observed that, to shelter that part, cavalry soldiers wear a long riding-cloak, which falls loosely over the hinder part of the animal.

Nature gives the horse a beautiful flowing tail and mane, for the purpose of whisking off flies, and for other uses; but mankind, in taking the creature under their protection, have in many instances, and for no good reason, as far as we are aware, deprived it of these graceful personal appendages. The most contemptible piece of this rash interference has been the docking of the tail, and causing it to cock up, thus leaving the rear of the animal exposed. The tail should be left flowing to a point, and only trimmed to a limited extent; and the same thing may be said of the mane. Nature has likewise given the animal long hairs on the legs, independently of the fetlocks. These various appendages have likewise not been given unnecessarily; they answer as a kind of thatch to carry off the moisture which trickles down the legs, so as to keep the feet dry and the legs warm. These parts, therefore, should be trimmed sparingly; and the fouler the animal's work, the more should be left on. Any trimming should be executed tastefully with a comb and pair of scissors. It is customary to clip away the long hairs about the ears and muzzle, but this also must be performed with great discretion. These hairs have their uses, those about the ears in particular, and harm is not unfrequently done by their removal.

Management of the Feet.

When the horse has been stabled for the night, it will be the duty of the groom to see that the hoofs, above and below, have been cleaned, particles of sand removed from the crevices of the shoes, and the feet generally in a good condition. The feet have a tendency to harden and crack, and thus a good horse may become lame. The fore-feet are most liable to this serious evil. To prevent hardness and soreness of feet, it is customary to *stop* them at night with a soft moist material—most commonly cow-dung, mixed with oil, lard, or tar. No special directions on this point can be given; for some thin-soled horses do not require stopping, and the hind-feet are seldom in need of anything of the kind. When the frog is liable to thrush, the feet require to be kept dry, and cleaned and attended to with peculiar care. To prevent over-dryness of hoofs, as well as the undue action of moisture, it is advisable to anoint the horny part of the feet with an ointment made of tar, fish-oil, and bees-wax, melted together in equal proportions; but this should not be done unless it is absolutely required. If well washed, and kept clean, the feet will seldom require any of this kind of varnishing.

When at large in a wild state, horses, as may be supposed, go barefooted, like all the other lower animals. The hoofs grow with a slight curve up in front; but this does not seem to impair their speed. If domesticated horses were always to walk on turf, and were not obliged to carry or draw a weight, their feet might remain unshod; but the circumstances of their condition make it necessary to protect the hoofs from tear and wear by means of shoes. Horseshoes have been used of many different shapes and materials; but it is needless here to speak of any others than the iron shoes in common use. The shoe must be of weight conformable to the powers and uses of the animal, made exactly to suit the curve of the hoof, flat, and of equal thickness, and secured by nails to the hoof. The proper paring of the hoof before shoeing, and the shoeing itself, are matters to be left to the discretion of regular farriers. As a general principle, care must be taken not to drive the nails into any tender part, and the hoof should be as little broken as possible. A gentleman's horse should be shod at regular intervals of three or four weeks, and a shoe never suffered to come off from too long usage.

Exercise.

Every horse, when not worked, ought to be exercised daily in the open air. The exercise should be in the early part of the day. An authority already quoted (*Lib. Use. Know.*) observes: 'The horse that, with the usual stable-feeding, stands idle for three or four days, as is the case in many establishments, must suffer. He is disposed to fever, or to grease, or, most of all, to diseases of the foot; and if, after these three or four days of inactivity, he is ridden fast and far, is almost sure to have inflammation of the lungs or of the feet. A gentleman's or tradesman's horse suffers a great deal more from idleness than he does from work. A stable-fed horse should have two hours' exercise every day, if he is to be kept free from disease. Nothing of extraordinary, or even of ordinary labour can be effected on the road or in the field without sufficient and regular exercise. It is this alone which can give energy to the system, or develop the powers of any animal. In training the hunter and the race-horse, regular exercise is the most important of all considerations, however it may be forgotten in the usual management of the stable. The exercised horse will discharge his task, and sometimes a severe one, with ease and pleasure, while the idle and neglected one will be fatigued ere half his labour be accomplished; and if he be pushed a little too far, dangerous inflammation will ensue. How often, nevertheless, does it happen that the horse which has stood inactive in the stable three or four days, is ridden or driven thirty or forty miles in the course of a single day? This rest is often purposely given, to prepare for extra exertion—to lay in a stock of strength for the performance of the task required of him; and then the owner is surprised and dissatisfied if the animal is fairly knocked up, or, possibly, becomes seriously ill. Regular and gradually increasing exercise would have made the same horse appear a treasure to his owner. Exercise should be somewhat proportioned to the age of the horse. A young horse requires more than an old one. Nature has given to young animals of every kind a disposition to activity; but the exercise must not be violent. A great deal depends upon the manner in which it is given. To preserve the temper, and to promote health, it should be moderate, at least at the beginning and the termination. The rapid trot, or even the gallop, may be resorted to in the middle of the exercise, but the horse must be brought in cool. If the owner would seldom intrust his horse to boys, and would insist on the exercise being taken within sight, or in the

neighbourhood of his residence, many an accident and irreparable injury would be avoided. It should be the owner's pleasure, and is his interest, personally to attend to all these things.'

Watering and Feeding.

A horse should be exercised a little after being watered. He should on no account be allowed to drink when heated, particularly if heated to the extent of perspiring. The only refreshment allowed in these circumstances is a rinsing of the mouth, and the muzzle may be washed and relieved of froth. When not permitted to take water of his own accord in the stall, let him be offered a pail three or four times a day; and after drinking copiously at either a pail or pond, he may be trotted or gently cantered, the motion being generative of heat, and at least prevents any chill.

Horses are fed on different materials in different countries; but principally on the various kinds of grasses and cereal grains. The Germans give them feeds of brown bread while on a journey; in India, rice and spices are employed for their diet; in England, the chief articles of food are oats and hay, with inferior proportions of beans, peas, cut straw, and bran. The quantity, and also the nature of the food, will depend on the habits of the animal, and the work to which he is put. If the work be hard, he must be fed to a considerable extent on oats and beans, which are more nutritious than most other articles in use; but if the work be light, a lighter diet of hay, with perhaps only a small quantity of oats, will suffice. The stomach of the horse being small, he cannot eat much at a time; and it is always preferable to feed him often, and at regular intervals, than to offer him large feeds at irregular periods. There is another reason for offering small feeds: the horse nauseates food which he has blown upon, or previously touched, and will accordingly reject it if offered a second time, or allowed to stand beside him. For various reasons, therefore, it is better to give him only a little at a time, so as to leave none behind. If the animal be a poor feeder, or apt to waste his food, greater care must be taken in this respect.

Oats ought to be sound, old, and dry. If musty, reject them. In almost all cases, it is preferable to have them bruised; for by this they are more easily digested and nourishing than if left whole. It is now customary to mix oats with chaff composed of the cuttings of clover or meadow-hay, and the straw of wheat, oats, or barley. In some stables, a machine is kept to cut these materials. The length of the cuttings should be about half an inch. Bruised oats have a tendency to scour the animal; but the admixture of chopped stuff counteracts this quality.

Of hay, clover, and meadow-hay, little need be said. They should be sound and sweet-flavoured, without any mustiness. The hay should, if possible, be a year old, and well saved for use in an adjacent stack. Some horses are fond of peas; but they require to be given with caution, as they are apt to swell in the stomach. Almost all horses are inordinately fond of carrots, which, when administered in small quantities, do not purge the animal, and improve his coat. A respectable authority states, that 'for agricultural and cart horses, eight pounds of oats and two of beans should be added to every twenty pounds of chaff; and thirty-four or thirty-six pounds of the mixture will be sufficient for any moderate-sized horse [daily] with fair or even hard work.' In this estimate, no hay is supposed to be given. When the horse is fed on the last two articles, hay and oats, four feeds, or nine or ten pounds of oats per day, will be a fair allowance during winter, and in the case of moderate work; but in summer, half the quantity, along with a proportion of green herbage, will suffice. Many gentlemen follow a general rule of allowing twelve pounds of oats per day to each riding-horse, and this is given in three or four meals. A pony, having but moderate work, will be well fed on six pounds of oats per day with a fair proportion of hay. Latterly, sago has come into use as an article of horse-diet; and we believe it is tolerably nutritive, and may be employed to a certain extent to supersede oats, or to be mixed with them. It should be partially softened by preparation.

THE DISEASES OF HORSES.

In consequence of the general mismanagement and ill-treatment of horses, they are exposed to a number of formidable diseases. Those of most frequent occurrence are inflammation of the lungs, broken-wind, inflammation of the bowels, and certain illnesses of the feet and legs. Referring our readers to larger works on the horse for full information on these diseases, and recommending all unskilled persons at once to hand over their horse to a veterinary surgeon when unwell, we propose only to give a few hints as to the best means of prevention. The institution of schools of veterinary surgery, at which the anatomy, peculiar nature, and diseases of horses are explained by men skilled in this important department of science, has been a powerful auxiliary in improving the qualities of horses, preserving their lives, and saving them from much needless distress.

Inflammation.

The more ordinary inflammation is that of the lungs, and is caused by sudden changes of temperature; it is, in reality, the grand disorder of the horse, and its effects are only paralleled by those of pulmonary consumption in the human species. Already we have spoken of the great impropriety of exposing horses, while heated, to cold draughts. Allowing them to stand any length of time in the open air, in cold or moist weather, is equally objectionable, and positively cruel. Inflammation of the lungs, however, will arise from various causes besides cold, and these have engaged the most serious attention of veterinarians.

In a prize-essay awarded several years ago by the Highland Society to Mr M. Milburn, Yorkshire, the essayist observes: 'The post-horse, and such as are required to perform fast work, are more liable than heavier draught-horses to diseases of the brain, the nerves, and the lungs, simply because their work consists of rapid and powerful exertion; the farm-horse, the animal of long and steady exertion, to gripes, inflammation of the bowels, and stomach-staggers—results, as I shall presently shew, of a management unsuited to the character of the labour we require from them. The stomach of the horse is remarkably small—smaller in proportion to his size, and the quantity of food he requires, than any other domestic animal. Nature intends for him a supply of nutritious food, and that *at short intervals;* wherein he materially differs from the ox, whose capacious stomach will contain food which will not be digested for hours. The post-horse, the hunter, and the carriage-horse, have food of the most nutritious description, and the time during which they are worked is necessarily short, owing to the extreme exertion required; they return to their food; and although their appetite may for a time be impaired, and their stomach and bowels affected by the general debility of the system, yet they recover their tone as soon as the rest of the frame admits of their taking food. The farmer's horse, on the contrary, has food of a less nourishing nature; his rack is filled with straw, or at best with clover; the ploughman rises early, gives him a feed of corn, and leads him to his work, where he continues for seven, eight, and even nine hours, and his whole day's work is completed before he is allowed to eat. We do not find the ox, worked under similar circumstances, so affected in the stomach and bowels, simply because his capacious stomach, when filled, requires many hours to empty; while, as we have seen, it is different with the horse. Debilitated and hungry, the horse returns, and his rack

is plentifully supplied, and a good feed of corn given him, and he is left to himself: he eats voraciously, half masticates his food, loads his debilitated stomach, and his digestive organs are weakened, and permanently injured. This course is repeated—a habit of voracity is acquired; and at no very remote period the food lodges and obstructs the pyloric orifice—the passage from the stomach to the bowels—fermentation ensues, gas is evolved, the stomach is distended, he grows sluggish and sleepy, drops his head upon his manger; or he is delirious, and evinces that the sympathy which exists between the stomach and the brain has excited the latter organ; he rolls, paws, and is seized with convulsions; at length he expires, and he has died of stomach-staggers. The half-masticated food has irritated the bowels, extra exertion of the muscles has been required to propel the fæces to the rectum, and colic or cramp (spasms) of the bowels has followed; or a course of continued irritation, or of continued colic, or both, has ended in inflammation of the bowels. I remember a beautiful farm-horse, which, owing to the distance of part of the farm to which he belonged from the buildings, was worked the long hours described, and finished his day's work before his bait. He was constantly subject to attacks of the gripes, which were subdued; but he died of stomach-staggers. The same stable, then so often subject to diseases, is now, by a change in the system, completely free from them. Another case, however, occurred: a beautiful compact little mare was constantly afflicted by colic; she eventually died of inflammation of the intestines.

'There are other parts of the management to which horses employed in agriculture are subject, which induce diseases of the bowels. For instance, a boy returning from work, with heated and sweating horses, to save himself trouble, allows them to drink copiously at some pool or stream he passes. Suddenly one or more of the horses exhibit symptoms of gripes; they suddenly lie down, roll about, look at their sides, rise up, seem relieved, and again speedily relapse; the sudden application of the cold water has produced spasms in the bowels, through which it has passed. This is neglected, or perhaps gin or whisky, aided by pepper, is administered as a remedy, and severe and general inflammation of the bowels is the result: this is mistaken for another attack, and again the poison is administered, and the inflammation increased, and death follows. The horse of heavy work, too, is longer exposed to the inclemencies of the weather than the animal of light work. In the former, the rain is allowed to fall upon him for hours, and then *to dry upon his back:* the sympathy between the skin and the alimentary organs is known to every groom; obstructed perspiration, and consequent irritability, is conveyed from the one to the other, and disease is the consequence. It is true the latter is also partly exposed to the rain, but for shorter periods, and the wisp and brush are liberally applied when he enters the stable; a determination of blood takes place to the skin, perspiration is promoted, and disease thus prevented.

'Of the best means of preventing these diseases in farm-horses we will now treat: we have attributed the peculiar liability to them in farm-horses to mismanagement, with the exception of certain instances of peculiar formation of the animals; and although the farmer must necessarily work his horses longer hours than the horse of rapid work is capable, there is no necessity for depriving the animal so long of food. No horse should work more than five or six hours without a bait. If we examine the history of the stables of large farmers, whose fields necessarily lie at a great distance from the buildings, and where they are worked long in consequence, and compare it with that of small farmers under the contrary circumstances, we shall find a striking difference as respects the health of the animals. The case referred to above strikingly illustrates the truth of this observation. But it may be asked—How is it possible to bait the animals so far from home? The difficulty seems to be in procuring food upon the spot; for if this is not done, the precaution will be neglected, and at anyrate the land will be occupied by it. This, however, may be remedied. In the case, for instance, of a field intended for turnips, which has to be worked during the spring, a part of it, half an acre, or in proportion to the size of the field, may be sown with winter-tares, a few of which may be mown off, and given to the animals green, without carrying them from the field, interfering with any crop, or wasting any time in carrying the horses to a distance. If the field be intended for summer-fallow, the spring tare will answer, and which may be used in the same manner, instead of allowing the poor animals greedily and indiscriminately to crop the leaves of the hedges at every turning, from the impulse of hunger. There is another easy way of baiting, which some carters adopt, and which might be applied to the farmer's horse, especially when carting. It consists in securing a bag containing corn over the animal's mouth and nose, by a string, which passes over the poll, and is locally denominated a "nose-bag," or "horse-poke," and which should be removed when he has finished his feed. To prevent the effects of the wet upon the skin, an unexpensive glazed cloth may be thrown over the horse's back, and secured to the collar and traces. This may by some be considered very troublesome; but it will be found that when it is once begun, it will be considered no more trouble than carrying the rest of the harness; and if disease is prevented, the trouble amounts to nothing. To counteract as much as possible any habits of greedy feeding which the horse may have acquired, his corn should be mixed with chopped straw, or chopped clover, which will secure its proper mastication, and prevent many troublesome complaints, as well as render all the nutrition of the food available. These may be substituted by an admixture of clean chaff with corn—a plan which is pursued in a farm-stable with which I am acquainted, and is found a useful practice. It would save the animals much time in eating if all their food was chopped, and perhaps steamed; but on this subject we have not sufficient data to determine with accuracy.'

The cure, it has been hinted, must generally be left to the veterinary practitioner, whose chief object should be to empty the stomach. In severe cases, an ounce of laudanum and a drachm of pounded ginger, in a quart of warm ale, may be used with probable success.

Broken-wind.

When the breathing of a horse is rapid and laborious, it is said to be *thick-winded;* and when it breathes irregularly, the inspiration taking one effort, and the expiration two, it is called *broken-wind.* Inflammation of the lungs from cold is a cause of thick-wind, the condition of these organs preventing the full action of the air-tubes. The chief cause of broken-wind is sharp work after over-feeding—causing the animal to run while the stomach is full. Grossly fed, badly managed horses, are hence most subject to the complaint. Carriage and coach horses are seldom broken-winded, unless they bring the disease to their work, for they live principally on corn, and their work is regular, and care is taken that they shall not be fed immediately before their work. The farmer's horse is the broken-winded horse, because the food on which he is fed is bulky, and too often selected on account of its cheapness; because there is little regularity in the management of most of the farmer's stables, or the work of his teams; and because, after many an hour's fasting, the horses are often suffered to gorge themselves with this bulky food; and then, with the stomach pressing upon the lungs, and almost impeding ordinary respiration, they are put again to work, and sometimes to that which requires considerable exertion. The agriculturist knows that many a horse becomes

broken-winded in the straw-yard. There is little nutriment in the provender which he there finds; and to obtain enough for the support of life, he is compelled to keep the stomach constantly full, and pressing upon the lungs. Some animals have come up from grass broken-winded that went out perfectly sound. The exact nature of the disease is unknown. It appears, however, to consist in a paralysed condition of the bronchial tubes and remoter air-cells, which renders expiration more difficult, and necessitates the double effort so characteristic of the malady.

'The cure of a broken-winded horse no one ever witnessed; yet much may be done in the way of palliation. The food of the animal should consist of much nutriment condensed into a small compass; the quantity of oats should be increased, and that of hay proportionably diminished, the moistening of the hay is also usually beneficial; the bowels should be gently relaxed by the frequent use of mashes; water should be given sparingly through the day, although at night the thirst of the animal should be fully satisfied; and exercise should never be taken when the stomach is full.' Under such management, and at slow work, a broken-winded horse will often remain serviceable for years.

Curb—Bog-spavin—Bone-spavin.

The hock-joint is particularly liable to derangement, so as to render the animal unsound. One of these affections is called *curb*, which arises from overexertion of the ligaments, and takes the form of an enlargement a few inches beneath the joint of the hock. A more serious complaint of the hock is the *bog-spavin*, which takes place from overexertion, and is an inflammation in the vesicles containing the lubricating material for the joint. This disease is almost incurable; and the poor animal is in general only fit for ordinary and moderate work all the rest of his life. The *bone-spavin* is a still more formidable disease. It is an affection of the bones of the hock-joint, caused by violent action, or any kind of shoeing which throws an undue strain on certain ligaments, and deranges the action of the bones. A bony deposit takes place, the joint is stiffened, and the consequence is a lameness or stiff motion in the hind-legs. Blistering as a counter-irritant, and rest, are the principal remedies prescribed for this complaint; but the best thing of all, so as to *prevent* not only this, but all other similar complaints, is never to overload the horse, or put him, especially before he comes to his full strength, to any violent exertion.

Physicking.

Horses even when attended to with the greatest care, occasionally get into a condition which requires physic—that is, purgative medicine; as, for example, when they have been too long on hard food, and require a laxative; when they get into a heated state of body from constant high-feeding; when their bowels get overloaded or disordered; or when they are getting too fat. The most simple laxative is a *bran-mash*. Bran is put into a pail, and softened with boiling water; when cooled sufficiently, it is given to the animal as the last feed at night, instead of corn or hay. About half a pailful is a dose. Horses used by commercial travellers or others during the whole week, and fed on corn, are indulged in a mash on Saturday night; and this, with the rest on Sunday, keeps them in good condition. When a working-horse is lamed, or becomes sick, and must remain idle for a few days, he requires to be relieved by a dose of physic. Generally, this consists of from four to seven drachms of Barbadoes aloes, powdered, and formed into a round moistened mass, fit to be swallowed. It requires to be administered by a skilful groom, who will push it over the throat adroitly, without alarming the animal. Sometimes the powder is mixed with a little Castile soap. An hour or less after taking physic, a bran-mash should be given, and then the horse be gently exercised. On his return to the stable, he may be offered a drink of water from which the chill is taken, or as warm as he will take it.

We should consider it imprudent to offer any further explanations of the materia medica of horses; and again recommend all unskilled or but partially instructed persons not to attempt doctoring their horses themselves, but to obtain at once the advice of a veterinary surgeon.

ADVICE IN PURCHASING A HORSE.

The purchasing of a horse is ordinarily a matter of very serious difficulty, in consequence of the proverbial trickiness of dealers, and the many defective points in the animal's constitution, which cannot be seen with all the care that may be bestowed. In offering any hints on this important particular, we must refer to the instructions of authorities whose testimony is worthy of confidence. Mr Stewart has written a valuable little manual, entitled *Advice to the Purchasers of Horses*, which should be in the hands of all who have frequent occasion to make purchases. The following are a few of his admonitions:

'In buying a horse, one of the chief requisites to be attended to is the degree of nervous energy which the animal possesses; and it is the union of this energy with good conformation that makes many horses invaluable. Its absence or presence, however, is not likely to be discovered by the purchaser without a trial; and to avoid disappointment in this respect, it is therefore advisable to obtain one prior to purchase. The horse should be set to the work he will be called on to perform; and if he is intended for the saddle or single harness, he should have no companion on his trial, for many animals work well in company that are downright sluggards when alone. Some horses have an unpleasant way of going, or are difficult to manage, or have some vice which is only displayed when at work: these are so many more reasons for having a trial prior to striking a bargain. But if that cannot be obtained, some sort of conclusion regarding the animal's spirit may be drawn from his general appearance. The way he carries his head, his attention to surrounding objects, his gait, and the lively motion of his ears, may all or each be looked to as indicative of "bottom," or willingness to work. It is only, however, in a private stable, or in that of a respectable dealer, that these *criteria* can be depended upon; for in a market-place, the animal is too much excited by the cracking of whips, and the too frequent application of them, to be judged of as regards his temper. Neither must the buyer be thrown off his guard by the animation which horses display at an auction, or on coming out of the stable of a petty dealer; for it is a fact, which cannot be too well made known, that there are many unprincipled dealers who make it their business, before shewing a horse, "to put some life in him"—that is, they torture him with the lash, till, between pain and fear, the poor animal is so much excited, as to bound from side to side with his utmost agility at the least sound or movement of the bystanders.'

This writer continues, in relation to the head and other parts of the animal: 'The head, as being a part not at all contributing to progression, should in the saddle-horse be small, that it may be light; the nostrils expanded, to admit plenty of air, and the space between the branches of the lower jaw, called the channel, should be wide, that there may be plenty of room for the head of the windpipe. In the draught-horse, a heavy head is not, so far as utility is concerned, an objection, for it enables him to throw some weight into the collar; and hence, excepting its ugliness, it is rather an advantage, if he is used entirely for draught. But it makes the saddle-horse bear heavy on the hand of the rider, makes him liable to stumble, and, when placed at the end of

a long neck, is apt to wear out the fore-feet and legs by its great weight. The neck of the saddle-horse should be thin, not too much arched, and rather short than long, for the same reason that the head should be light; and in the draught-horse it may be thick, stallion-like, and sufficiently long to afford plenty of room for the collar, and for the same reason that the head may be large in this animal. The windpipe should be large, and standing well out from the neck, that the air may have an easy passage to and from the lungs. A horse intended to be used for the miscellaneous purposes of carriage and draught, should have a head and neck neither too light nor too heavy.

'That the saddle-horse may be safe, and have extensive action, it is necessary that the withers be high. This advantage is indicated by the horse standing well up before; and it is usual, in shewing a horse, to exaggerate the height of the forehand by making him stand with his fore-feet on a somewhat elevated spot. A horse with low withers appears thick and cloddy about the shoulder. In the ass and mule, the withers are very low, and the shoulders very flat, and this is the reason why they are so unpleasant to ride, and why it is next to impossible to keep the saddle in its proper place without the aid of a crupper. High withers, however, are not essential to the racer or the draught-horse. The former does all his work by leaps, and that is performed best when the horse stands somewhat higher behind than before: neither are high withers necessary to the draught-horse; but in the roadster, they are as important as the safety of the rider is, for a horse with a low forehand is easily thrown on his knees. In the draught-horse, this tendency towards the ground is obviated by the support the collar affords.

'The chest should be deep and wide in all horses, but especially so in one intended for quick work, in order that there may be plenty of room for the play of those important organs, the lungs.

'The back should not be too long nor too short; for though length is favourable to an extended stride and rapid motion, yet it makes the horse weak, and unable either to draw or carry any considerable weight. On the other hand, if the back be too short, the horse's action must be confined; and short-backed horses, in general, make an unpleasant noise when trotting, by striking the shoe of the hind-foot against the shoe of the fore one; and though they are in general very hardy, and capable of enduring much fatigue, and of living on but little food, yet a back of middling length is better by far than one immoderately short or long. The back should be nearly straight.

'In the saddle-horse, and where safety is desirable, the position of the fore-leg is worthy of attention. It should be placed well forward, and descend perpendicularly to the ground, the toe being nearly in a line with the point of the shoulder. The pasterns should neither be turned in nor out. When they are turned inwards, the horse is in general very liable to cut the fetlock-joint by striking the opposite foot against it. The draught-horse may be excused though he leans a little over his fore-legs, but the saddle-horse will be apt to stumble if he does so.'

Minute attention should be bestowed on the examination of the fore-legs and feet; these, in fact, are the great trying-points. If the feet be not round and full, so as to stand firmly and flatly on the ground, and if tender or thin in the hoofs, the animal is not to be trusted for saddle-work. Mr Lawrence on this subject remarks: 'The feet of saddle-horses, be they ever so sound and good in nature, detract greatly from the value of the nag, unless they stand even on the ground; since, if they deviate inward or outward, the horse will either knock or cut in the speed—that is to say, will strike and wound the opposite pasterns either with his toe or his heel; and if he bend his knees much, and is a high goer, will cut the inside of the knee-joint. Nature has been very favourable in the hinder hoofs, with which we have seldom much trouble; but there is, now and then, a most perilous defect in them—namely, when the horse is so formed in his hinder quarters that he overreaches, and wounds his fore-heels with the toes of his hind-feet.' The defect here spoken of will be observed to cause an unpleasant clattering noise in trotting. The fore-legs, from the knees downwards, should be clean made, sound, and flexible at the joints. Bad usage knocks up a horse, or founders him; and his legs, being in a kind of benumbed state, will either wholly or partially refuse to perform their office. By ease and physicking, the horse recovers; but his system has been shaken, and he is apt to come down. This is a fearful defect in a horse; for no one is for a moment safe on his back. Weakness in the fetlock-joint will also cause a horse to stumble and come down, and is therefore an equally serious defect. When the horse stumbles either through weakness or bad management, so as to come down on his knees, the likelihood is, that the knees are broken; and it is well known that wounds of this nature never heal over to resemble the original. The horse with broken knees is, in short, damaged for life, at least in as far as he is a marketable commodity.

Horses are sold either with or without warranty. At sales at repositories, the terms of warranty are generally announced in a public manner; but when the sale is private, no warranty is binding which is not expressed in writing in the receipt. The principle that a price above £10 warrants a horse sound, is not now recognised as binding. The warranty, to be of any legal value, must be something different from a mere verbal understanding or illusory custom.

DUTY OF HORSES.

Draught.

The horse is equally willing to make himself useful as a beast of burden or draught; but his powers are best adapted for the latter, and particularly on a level road. The formation of his body does not suit him for climbing or going uphill with a load; and his strength is always exerted to greatest advantage when he can throw his centre of gravity forward as a make-weight. The amount of load which he can draw in a wheeled vehicle depends on the arrangement of the load to the pull. The pulling-point is across the shoulders, and the most advantageous method is, to make the line of traction proceed *direct* from the shoulders to the load—in no shape bent or distracted from its course. The load should be placed lower than the line of the shoulders, thus making the line of traction go by a straight slope to the seat of resistance. The load should not be at a greater distance than will allow freedom of motion to the hind-legs. If it be placed too low, a part of the power will be uselessly spent in upholding it.

According to the calculations of James Watt, the weight which a horse can draw, called a *horse-power*, is 1,980,000 pounds raised one foot high per hour, or 33,000 pounds raised one foot per minute. The weight is supposed to hang at the end of a rope passing over a freely-moving pulley. This calculation is based on considerations more favourable than those which usually attend horse-labour. There are, in reality, no rules to guide the imposing of loads on horses; for everything depends on the degree of friction on the wheels of the carriage, the nature of the road, and the strength of the animal in question. One thing is certain, that a horse always exerts his power better by himself than when yoked with others. The load which it requires four horses to draw unitedly, if divided, could be drawn with equal ease by three. The following observations, referring to the operations of Sir C. Stuart Menteith, deserve to be noticed:

'From the experience this gentleman has had in the

use of animal power upon common roads, he is of opinion that the most economical mode of employing horses in draught is to give every horse his own carriage, and that he should solely depend upon his own exertions in drawing the load, as otherwise it is well known that it is difficult to find either man or beast equally willing or capable to make the same exertion, or to have the same spirit or motion; and at the same time never to exceed six miles on one stage, and to be performed twice daily. In a stage of three and a half miles, Sir C. S. Menteith employs wagons weighing eighteen hundredweights, in which horses draw three tons. The road is in general upon a declivity of one foot of fall for every eight, sixteen, or eighteen feet, with several ascents of one foot in every thirty feet, up which a horse draws the load of three tons, and a wagon of eighteen hundredweights; but in order to facilitate the ascent, a continuous line of sandstone railroad is first laid down, upon which a plate of iron, six inches wide by a quarter of an inch thick, is fixed down. In order to enable a horse to bring a load of three tons down any rate of descent, a friction-break has been employed, similar to the one in common use in Belgium, from which Sir C. Stuart Menteith derived this important application. The break is a strong plank fixed to the back of a cart or wagon, which, by means of a screw, the carter presses against the two hind-wheels of the machine, so as to give a sufficiency of friction to retard the too rapid descent of the carriage. If the employment of horse-wagons, weighing from twelve to thirteen hundredweights, were adopted in conveying coal through the streets of London, one horse would do the work of two: at present, four immense horses draw three chaldrons of coal, or four tons one hundredweight, in a wagon weighing perhaps two tons; so that the shaft-horse is obliged to draw a weight of six tons in turning out of one street into another.'

The larger the size of wheels in a vehicle, within a reasonable proportion, so is the friction in overcoming obstacles on the road less, and so is the draught more easy to the horses. The benefits of large wheels, however, have often been completely lost by not making them run fairly in an upright position. The custom has been to make them *dished* or bevelled outward from the axle, and to cause the axle to lean downward at each extremity to accommodate this peculiar shape. It is of importance to understand that a wheel always runs best when its tire is of equal diameter, when the spokes are at right angles to the axle, and when the axle projects straight out. This is exemplified in the trundling of a hoop: a hoop which is perfectly upright and even on the rim, requires less force to send it forward and keep it moving than if it were bevelled, and inclined to go round in a circle. For the sake of convenience, wheels may be a little dished, though now, that the roads are good, that is scarcely necessary.

The power of draught of a horse depends on the rate at which he is compelled to proceed. He exerts his power to most advantage at a fair pull, when moving at the rate of from two and a half to three miles per hour. If he go at a greater speed, he is less able to draw. As a general rule, if the speed be doubled, the load should be halved; and if the speed be twice doubled, the load should be quartered; yet this will only hold as correct for short distances. Much work may be procured from a horse if he be impelled only for short stages. A horse in a stage-coach, running only five miles at a time, and then resting for a few hours, will last at least four times longer than another horse of equal power which runs ten miles at a time. This is well understood by all stage-coach proprietors, and short stages have now almost everywhere superseded long ones. Such a fact should also be known to all private travellers. Whether employed in a gig, chaise, or for riding, the horse on a journey should take his day's work in two distinct stages—one in the morning, and another in the afternoon, when rested and refreshed. He should also, to remain in good condition, have a rest during the whole of Sunday. In journeying with light loads, a distance of from twenty to twenty-five miles is considered a sufficient day's task.

Riding.

The art of riding or equitation forms a regular branch of instruction, and is seldom well performed by those who have not been regularly taught. It is not to be supposed that anything we can say can supersede the instructions of the riding-school; but it may be of use to offer a few hints on the subject from the most esteemed authorities.

Riding should be performed in that manner which is least calculated to oppress the horse and fatigue the rider, and which will be most secure for both parties. The first principle in horsemanship is, that the horse and his rider should act and react on each other as if governed by one common feeling. To attain this end, the rider must acquire the knack of balancing himself properly on the animal, and establishing the means of making himself understood through certain movements of hand and body. A good horseman will act according to the following directions, given in Walker's *Manly Exercises*: 'The place of the rider's seat is that part of the saddle into which the rider's body would naturally slide were he to ride without stirrups. This seat is to be preserved only by a proper balance of the body, and its adaptation to even the most violent counteractions of the horse. In relation to the thighs, the rider, sitting in the middle of the saddle, must rest chiefly upon their division, vulgarly called the fork, and very slightly upon the hips. The thighs, turned inward, must rest flat upon the sides of the saddle, without grasping; for the rider's weight gives sufficient hold, and the pressure of the thighs on the saddle would only lift him above it. The knees must be stretched down and kept back, so as to place the thighs several degrees short of a perpendicular; but no gripe must be made with them, unless there be danger of losing all other hold. If the thighs are upon their inner or flat side in the saddle, both the legs and the feet will be turned as they ought to be. Thus turned, they must be on a line parallel to that of the rider's body, and hang near the horse's sides, but must not touch; yet they may give an additional hold to the seat, when necessary, and the calves must act in support of the aids of the hands. The heels are to be sunk, and the toes to be raised, and as near the horse as the heels, which prevents the heel touching the horse. As to the body, the head must be firm, yet free; the shoulders thrown back and kept square, so that no pull of the bridle may bring them forward. The chest must be advanced, and the small of the back bent a little forward. The upper parts of the arms must hang perpendicularly from the shoulders, the lower parts at right angles with the upper, so as to form a horizontal line from the elbow to the little finger. The elbows must be lightly closed to the hips, and, without stiffness, kept steady, or they destroy the hand. The wrist must be rounded a little outwards. The hands should be about three inches from the body, and from the pommel of the saddle, and from four to six inches apart; the thumbs and knuckles pointing towards each other, and the finger-nails towards the body. When the rider is in the proper position on horseback without stirrups, his nose, breast, knee, and instep are nearly in a line; and with stirrups, his nose, breast, knee, and toe are in a line. The man and the horse throughout are to be of a piece. When the horse is at liberty, or disunited as it is termed, the rider sits at his ease; and as he collects and unites his horse, so he collects and unites himself. There must, however, be no stiffness of manner more than in sitting on a chair; for it is ease and elegance which distinguish the gentleman.'

Riding, to one accustomed to it, is best performed

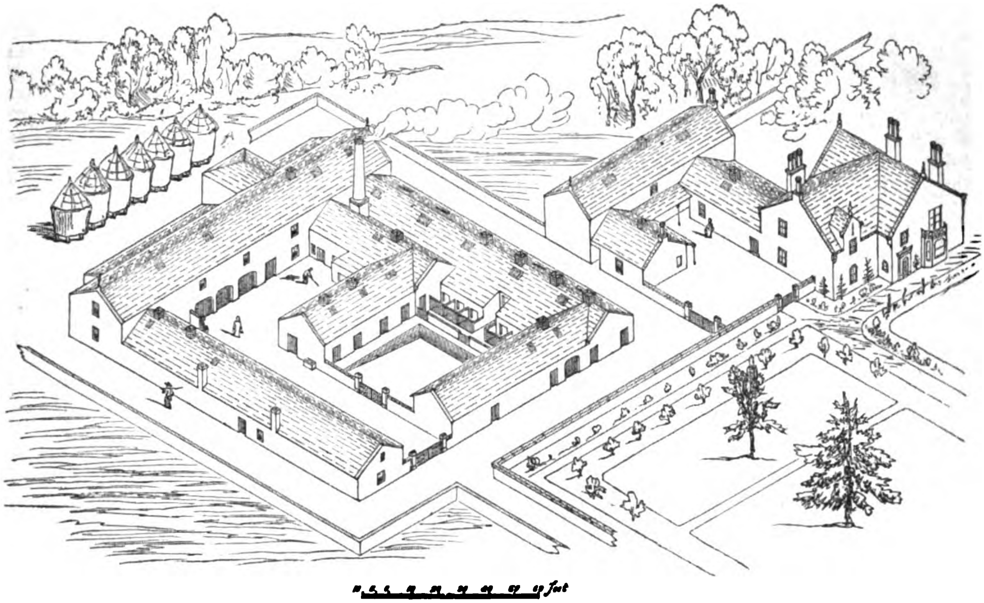
with a curb and snaffle bridle; the curb, however, being only employed to bring the animal up by pressure on the mouth when occasion requires. As some horses have a much more delicate mouth than others, the nature of the bridle must depend on circumstances. In holding the reins, a union of firmness, gentleness, and lightness is the essential requisite. The foregoing authority alludes to the manner in which the reins are to operate on the mouth of the animal: 'The hand being connected with the reins, the reins to the bit, the bit operating in the curb on the bars, and in the snaffle on the lips, the rider cannot move the hand, and scarcely even a finger, without the horse's mouth being more or less affected. This is called the *correspondence*. If, moreover, the hand be held steady, as the horse advances in the trot, the fingers will feel, by the contraction of the reins, a slight tug, occasioned by the cadence of every step; and this tug, by means of the correspondence, is reciprocally felt in the horse's mouth. This is called the *appui*. While this relation is preserved between the hand and mouth, the horse is in perfect obedience to the rider, and the hand directs him, in any position or action, with such ease, that the horse seems to work by the will of the rider rather than by the power of his hand. This is called the *support*. Now, the correspondence, or effective communication between the hand and mouth—the appui, or strength of the operation in the mouth—the support, or aid, the hand gives in the position or action, are always maintained in the *manège* and all united paces. Without these, a horse is under no immediate control, as in the extended gallop or at full speed, where it may require a hundred yards to pull before we can stop him. The degree of correspondence, appui, and support, depends, in horses otherwise similar, on the relative situation of the hand. The act of raising the rider's hand increases his power; and this—raising the horse's head—diminishes his power. Depressing the rider's hand, on the contrary, diminishes his power; and this—depressing the horse's head—increases his power.'

Much may be done to animate a horse, either in riding or drawing, by addressing a cheerful word to him, instead of the lashing and scolding with which he is too frequently visited. If a horse requires correction or urging by the whip, he should only be touched lightly behind the girth and saddle, never on any account on the head or on a fore part of the body. We have frequently seen riders so lost to humanity as to whip their horses when restive over the head and ears. Should a horse attempt to baffle his rider, he must be pressed by the legs, urged lightly with the spur, and kept in his proper track, but not drawn up with the curb or terrified by abuse.

The most common pace in road-riding is the trot, which, in effect, is a rapid walk, and most difficult for a rider to perform with address and a small degree of fatigue to himself. In slow trotting, the body should adhere to the saddle, and when it becomes fast or rough, the body may be raised at the proper moments to ease the jolting. This rising of the body, however, is to be a result of the horse's action, not an effort of the rider. The proper method is to rise and fall with the leading foot, the body rising from the seat when the foot is elevated, and falling when it sinks.

In the course of either slow or fast riding, the horse may trouble his rider by plunging, shying, or restiveness. If he kick and plunge, sit upright, hold on by the legs, and do not vex him by any lashing; when let alone, he is not long in coming out of his freak. When he shies, or flies to one side, as if afraid of something, press him on the side to which he is flying, keep up his head, and bring him into his track. Pressing both legs against his sides will generally keep him from running backward. When he becomes restive—that is, turns round, and has a disinclination to go in the way he is required, the rider must keep him in his track by dint of pressure, a touch of the spur, and the hand. If he has been accustomed to spurs, and finds that your heels are not provided with these appendages, your case is very hopeless. We must allow Walker to point out the course to be pursued with a restive horse. If he persists in turning round, the rider must continue 'to attack his unguarded side, turn him two or three times, and let the heel and spur, if necessary, assist the hand, before he can arm or defend himself against it. If he still refuse to go the right way, the rider must take care that he go no other, and immediately change his attack, turning him about and reining him backward, which the horse is easily compelled to do when he sets himself against going forward. In these contests, the rider must be collected, and have an eye to the surrounding objects; for restive horses try their utmost to place their riders in awkward situations, by sidling to other horses, carriages, the foot-pavement, the houses, &c. In this case, the rider, instead of pulling him from the wall, must bend his head to it, by which his side next the wall is rendered concave, and his utmost endeavours to do injury are prevented. The instant, therefore, that the rider perceives his horse sidling to any object, he must turn his head to that object, and back him from it. There are some horses who fix themselves like stocks, setting all endeavours to move them at defiance. There, happily, their defence can in no way endanger the rider. It must, however, be converted to punishment. Let them stand, make no attempt to move them, and in a short space—frequently less than a minute—they will move of themselves.' The same author recommends the rider to remain perfectly cool in all these awkward circumstances. 'When passion,' he observes, 'possesses the rider, it prevents that concord and unity taking place which ever should subsist between the rider and his horse. He should always be disposed to amity, and never suffer the most obstinate resistance of the horse to put him out of temper.'

Neither in the above section nor elsewhere have we said anything of the accoutrements of the horse, as every article of this kind must be left to the taste of the party concerned. The harness made by all saddlers is now handsome, convenient, and durable, and so well calculated for the comfort of the wearers, that it would be superfluous to say anything respecting it, further than to recommend that it be always kept clean and glossy, and that it do not gall or press unduly on any part of the animal's body.



Open-courted Steading for Dairy-farm of 250 acres.

CATTLE—DAIRY HUSBANDRY.

NEXT to the horse, the cow is justly valued as the most useful animal that man has been able to domesticate and retain permanently in his service. The ox tribe, of which it is the female, belongs to the order *Ruminantia*, in the class *Mammalia*—these terms implying that the animals ruminate or chew their food a second time, and have mammæ, or teats, with which they suckle their young. In the ox tribe (*Bovidæ*), there are different species, all more or less varying from each other. Of the domesticated ox (*Bos Taurus*), the varieties, from the effect of climate, with attention to selection and care in feeding, are now very numerous. The ox, in one or other of its varieties, has been domesticated and carefully reared from the earliest times, for the sake of its labour as a beast of draught, for its flesh, or for the milk of its female. In some parts of Asia, the ox is used for riding and for carrying burdens, similar to the camel in the East, or the packhorse in Europe. In ancient Egypt the ox was raised to the rank of a divinity; while in India, at the present time, he is by several of the Hindoo castes, held as an object of extreme veneration.

The domesticated species of the family, common to the British Isles and Europe generally, is, in all its varieties, materially altered from its wild parentage. Influenced by climate, peculiar feeding, and selection in the domesticated state, its bony structure is diminished in bulk, its ferocity tamed, and its tractability greatly improved. The ox in a wild state is kept at Hamilton Palace, and also at Chillingham Park, Northumberland. Our observations in the present sheet will refer chiefly to the domesticated ox, on which very great changes have been effected by domestication. The most remarkable of these is an increased capacity in the female for giving milk. In a wild state, the udder is small; but when domesticated for the sake of its milk, and the lactic fluid is drawn copiously from it by artificial means, the lacteal or milk-secreting vessels enlarge, and the udder expands, so as to become a prominent feature in the animal. In this manner, by constant attention, the economy of the cultivated species has been permanently altered, and rendered suitable to the demands which are made on the cow. Yet it is important to remark, that those milk-yielding powers are not equal in the different varieties or breeds. Some breeds, from the influence of circumstances which it is here unnecessary to inquire into, give a large quantity of milk; while others yield less, but of rich quality. The quantity and quality of the milk depend, however, on various conditions. The principal are, the age of the animal, the feeding, the housing, &c. In the more highly cultivated breeds, the variations in the flow and in the quality of the lactic fluid in different animals are often remarkable. The cause or causes are usually extremely difficult to account for. In general, near large towns, where the demand for milk is considerable, the object of dairymen is to keep cows which will give a large quantity of milk.

VARIETIES OR BREEDS.

The breeds of cattle throughout the United Kingdom vary in different districts, from the small hardy varieties of the Shetland and Orkney Isles, and the north and west Highlands, to the handsome and more bulky breeds of the arable districts.

Short-horn.

The *Short-horn* or *Teeswater* breed is considered of great value, both for milking and feeding. The best strains of blood are large in the carcass, well proportioned,

broad across the loins, chine full, legs short, head small and handsome, neck deep, in keeping with the size of the body, skin thin and mellow, colour generally white or red, or red and white mixed, or roan. The flesh of the Short-horn is thick and close-grained, the lean and fat well intermixed, and retains the juices. From this circumstance, it is in request for victualling ships going on long voyages.

Authorities are at variance with reference to the milking qualities of this breed; some asserting that, unless the climate and food are very favourable, they are seldom good milkers, having a greater tendency to produce fat than milk; others, again, maintaining that any deficiency in their milking capabilities arises not from the peculiarities of the breed, but from the neglect of breeders to develop the property of giving milk, their attention being chiefly bestowed on the development of flesh and fat. The dairies in London and the neighbourhood of the metropolis are generally occupied with cows of this breed, or of crosses of the Short-horn. As grazing-cattle, they stand first in point of value. Their 'aptitude to fatten,' says a writer in the *Cyclopædia of Agriculture*, 'and the amazing weight and maturity of carcass to which they attain while their age is only reckoned by months; their symmetrical form, rich colour, and quiet temper,' have 'secured to them the pre-eminence over all other cattle. So thoroughly, indeed, do they meet the requirements of our arable husbandry in its highest modes, that we may warrantably expect, at no distant day, to find them recognised as *the one appropriate breed* of the lowlands of the kingdom.' Animals of this breed generally realise high prices. At recent sales of herds of short-horns, the average prices of the whole—bulls, cows, heifers, and calves—ranged from £50 to upwards of £90. Occasionally, animals have been sold at sums almost fabulous; three having been bought in England at £1000 each, for Mr Thorne, state of New York, United States. A bull, three years old, named Master Butterfly, was purchased for Australia in 1856 for the sum of £1250. The demand for Short-horns is yearly increasing, and consequently higher prices are obtained for the best specimens of the breed.

The *Herefords* are to be found in perfection in the county from which the name is derived. They are of large size, with round cylindrical forms; the back and quarters broad; the head of moderate size; muzzle, broad; eye, large, prominent, and placid; horns of medium length, spreading outward and forward, with the points upward. The colour of the skin is almost uniformly deep red, with face white, and a white patch on the shoulder. Sometimes they have the ridge white, with belly and legs of corresponding colour. There is a strain of blood where the animals are nearly white, with brown spots. For the dairy, the Hereford is the least productive of all the English breeds. The secretion of milk is at no time great, and the period of lactation is short. The cows generally suckle the calves, nearly the whole of which are reared. As animals for labour, the Herefords are admirably adapted, from their great weight in the yoke, their quick step, and their generally healthy constitutions, enabling them to undergo considerable fatigue. They are now little used for field-work; it is for their value as grazers that the Herefords are prized. When well kept, they are ready for the butcher at two and a half years, but are not generally slaughtered till they reach three to four years. The flesh is evenly laid on, and on the best parts, giving less coarse meat than perhaps any other breed. The flesh is highly esteemed; but when fully fattened, there is an excess of fat. Oxen of this breed always appear to great advantage at the Christmas fat shows. The Hereford has been long deemed the rival of the Short-horn, and in the county of Hereford, is asserted to be superior.

The *Devons* occupy the third place in the English agricultural prize-lists. They are smaller in size, and more delicate in structure than the Hereford. When reared on the richer lands of Somersetshire, the size is considerably increased. Specimens are met with nearly as large as Herefords. Their form is symmetrical; the head, small; the eye, clear and placid; the horns are finely tapered, spread out and upward; the horn is longer than in the Hereford. The colour of the Devon is deep red, without any white marking. As dairy-stock, they occupy a medium place, the milk being rather rich than abundant. There are dairies of Devons containing about 100 cows, which are stated to yield a large return of dairy-produce. As oxen for labour, the Devons are much prized; hardy, active, and quick steppers, they perform nearly as much work as ordinary farm-horses: the want of weight, however, operates against their working in pairs. As beef-producers, they are inferior to the Hereford; the quality of the meat is indeed superior, but it is unequal. This is a general complaint against the Devon in the London dead-market.

The *Sussex* breed is somewhat similar in form, and identical in colour with the Devon; it stands higher from the ground, and is less symmetrical. It is inferior for the dairy, but nearly equals the Devon for labour. They are long of arriving at maturity; but when fattened, the beef is of good quality. As a breed, they are not equal to the Devon.

The *Suffolk and Norfolk* polled breed is supposed to be descended from the polled Galloway. They are of medium size, somewhat deficient in symmetry, but are roomy and wide-set. The colour is dark red to yellow. The milk-vessel is large, generally well placed. The Sussex and Norfolk are much esteemed for their milking properties. There are also horned breeds almost indigenous to these counties. The colour is similar to the polled breeds, but they are inferior as milkers.

The *Long-horn* or *Lancashire* was at one time much sought after, especially after its improvement by Robert Bakewell. This breed is now almost wholly superseded by the Short-horn. The Long-horn is distinguished by the length of its horns; these are usually curved in the form of a half-circle, and are pointed downward. The length and general rotundity of the body, with the large sizes they attain, give this breed a fine appearance. The skin is usually thick, colours brindled, ridge and belly white, with marled spots inside the legs. The absence of early maturity, with their inferiority as milkers, has caused the breed to be neglected. In some parts of Ireland, and in the counties of Oxford and Derby, there are breeders who still maintain the Long-horn pure; but the greater portion of those exposed in public markets are crosses. In the two English counties referred to, the breeders of the Long-horn attach a high value to their herds.

The following facts are significant of the estimation in which the Long-horn was at one time held. For the purpose of comparison, selections are made from two public sales—one of Long-horns, the other of Short-horns. The sale of Long-horns took place on the 27th of March 1791, the stock being the property of Mr Fowler, of Little Rollright, Oxfordshire; the sale of Short-horns took place on the 11th of October 1810, being that of the celebrated Mr Charles Collings, county of Durham.

LONG-HORN.

Bulls.

Garrick, ...	5 years old,	205 guineas.
Sultan, ...	2 " ,	210 "
Washington, ...	2 " ,	205 "
Young Sultan, . . .	1 year old,	200 "
	1 " ,	145 "
	1 " ,	100 "

Cows.

Brindled Beauty, ...		260 guineas.
Dam of Washington, ...		185 "

SHORT-HORN.

Bulls.

Comet,	6 years old,	1000 guineas.
Major,	3 "	200 "
Petrarch,	2 "	365 "
Young Favourite,	under 1 year,	140 "
Geerse,		180 "
Cecil,		170 "

Cows.

Lily,	3 years old,	410 guineas.
Countess,	9 "	400 "

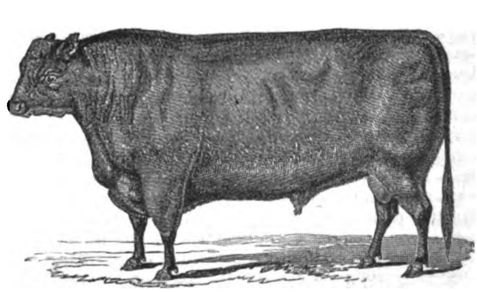
At Mr Page's sale, 14th of November 1793, Shakspeare, a bull (Long-horn), bred by Mr Fowler, was sold for 400 guineas; Mr R. Bakewell, in the spring of 1792, let a bull for four months for 152 guineas.

The *Alderney* is the most esteemed of the Channel Island cattle. They are delicate in form—colours varying from light red to fawn and dun—generally with white intermixed. The head is long and handsome; eye, large and prominent; horns, short and crumpled. As dairy-stock, they have been much lauded, particularly for the quality of the milk. One or two Alderney cows in a dairy are stated to impart a richness of colour to the butter. Such is the demand for cows of this breed, that it is believed a much greater number is annually sold in England than the Channel Islands produce. As the same breed exists in a part of Normandy, a portion of these may swell the number of the Alderneys sold in England. Dairymen in Scotland believe that either the climate of Scotland is too cold for the Alderney, or the qualities of the breed have been exaggerated. Where tried, they have seldom given much satisfaction.

In Wales, there are various breeds, but a family likeness pervades the whole. The most common are black in colour, of medium size, with the body long. The horns are of medium length, white, with black points, and pointed upwards. Like mountain breeds generally, they are active, hardy, and do not reach maturity till an advanced age. They usually stand well to the pail, but are not much esteemed as dairy-stock, except by cottagers. For labour, the Welsh oxen are only excelled by the Devon. Their hoofs are well adapted for travel, resisting the tear and wear of the most flinty and gravelly soils. In the counties bordering on Herefordshire, the cattle resemble somewhat the Hereford in form and colour, but are smaller in size, with less aptitude to fatten. The Pembroke and Glamorgan are the most esteemed. The former are generally dark brown, with white ridges. As milkers, both are superior to the Hereford. The Welsh cattle are much esteemed by the grazier. Droves of black Welsh may be observed grazing in fields over the greater portion of the southern counties of England; they are usually purchased in the Welsh markets at prices which may be considered moderate when contrasted with those paid for Herefords or for Short-horn crosses.

The *Ayrshire* is generally considered the most valuable for dairy purposes. It is of medium size; the horn is small, short, and bent inward, sometimes pointing upward. The body is long and low set; skin, thin, loose, and soft to the touch; the head, long and narrow at the muzzle; eye, large and lively, sometimes with a certain expression of wildness; the neck, long, and slender in the cow, with little muscle; the shoulder, sharp; the fore-quarters, light; ribs, well sprung; hind-quarters, long, wide, and deep; back, straight; legs, short; the bones, small, but joints somewhat loose and open. The udder is generally capacious, placed forward on the belly, and not extending backward beyond the buttock; the teats are wide apart, and generally small. To adapt them for the inferior pastures which is the character of nearly all dairy-farms in the west of Scotland, the young stock is kept in such a way as to stint them in growth. The Ayrshire, when reared in Ireland, or when treated liberally at home, is found to increase considerably in size; and if this quality were desired, by attention to feeding and selection, they could be reared to nearly double the weight that is generally esteemed the best for an Ayrshire cow. The heifers usually produce at little beyond two years, and are retained for the dairy till they reach seven or ten years. As beef-producers, the Ayrshires do not occupy a high place. When a Short-horn bull, however, is used, a very superior animal is produced for feeding purposes. This system is pursued by many farmers in the west of Scotland with great success, the stock being fattened off at two or two and a half years old, and realising nearly £1 a month for keep. The Ayrshire cow is more widely spread over Scotland than any other breed. Dairies of this breed occupy nearly the whole of the west of Scotland, from Wigton to Ayrshire. Taking Glasgow as the centre, a radius of thirty miles is nearly wholly occupied by this breed. The Ayrshire is exported to most continental states—Russia, Denmark, Sweden, France, &c.

Polled breeds.—Galloway, Angus, Aberdeen, &c., are peculiar to Scotland. The *Galloway* extends over a portion of the Border counties in the west of the island —Cumberland, Wigton, Dumfries, &c., and is named from the district of *Galloway*. In several of the south-eastern counties of Scotland, polled cattle are also found. They are there known as the Angus and Aberdeen polled. Fife, Kinross, and other counties produce some polled animals; but the Galloway, Angus, and Aberdeen polled cattle are the most generally esteemed. The polled cattle which are habitants of the east of Scotland, owe much of their present high character as beef-producing animals to several breeders, particularly to Mr Hugh Watson of Keillor, who, by a course of selection during fifty years, has, while increasing the size, given more



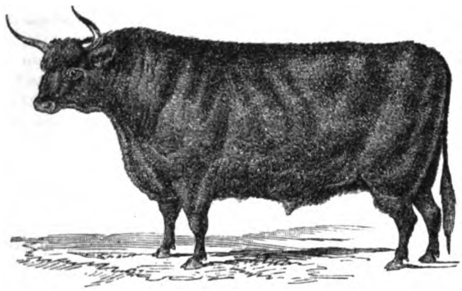
Polled Angus Bull.

symmetry, with greater aptitude to fatten. The above is a representation of a Polled Angus Bull, which was reared by this gentleman, and obtained the first prize at the Highland Society's meeting at Edinburgh in 1848. The polled Scots have all a family likeness; and the difference of climate between the west and east of Scotland accounts for the rougher coat of the Galloway. The polled Angus and Aberdeen are of larger size than the Galloway—nearly equalling the Short-horn; body, long and deep, but somewhat flat on the sides; skin of medium thickness; hair, short and glossy. The most esteemed colour is black. Occasionally, the udder and a portion of the belly are white marked. As milkers, the improved polled occupies a low place. As cattle for the yoke, they are equal to any British breed, being agile, quick-steppers, and hardy. They maintain their procreating powers to a longer period than any other British breed. There are several instances on record of cows breeding above the age of twenty years, and producing upwards of twenty calves. It is, however, as beef-producers that these polled breeds are so highly esteemed. A considerable portion are fattened in England; but as turnip-cultivation extends in the districts where they are

bred, the number which is annually fattened in the north is yearly increasing, almost the whole of which are sent direct to the London markets, live or dead. A cross between a well-selected Short-horn and these polled breeds produces superior animals—size, early maturity, and quality of flesh being combined.

In the counties of Aberdeen, Banff, &c., the horned breeds formerly bred, are gradually giving place to the pure polled, or crosses between the polled and Short-horn.

Highland cattle are much esteemed for the quality of the beef. The West Highland are the best known; they



West Highland Bull.

are found in the greatest perfection in Argyleshire and the Western Islands of Scotland. The above is a drawing of a West Highland bull, the property of Mr Duncan M'Naughton of Cashlie, which carried off the first prize at Edinburgh in 1848.* They are the most picturesque of all the British breeds; being handsome in form, straight from the head to the tail; body, round and symmetrical; legs, short and firmly set. The head is carried high; the forehead is protected by long shaggy hair; the eyes, large and lustrous; horns, long, spreading, and pointing upwards. The skin is usually thick, covered with a coating of shaggy hair, which protects them from the moist and stormy climate of their native hills. The colour is generally black; but they are to be found of all colours, from the light yellow or gray, almost white, to the deep yellow, red, and duns. The variety in colours heightens the picturesqueness of a herd of Highland cattle. They are at first small in size, but they increase rapidly when transferred to the rich pastures of the south, and are usually to be found grazing in the vicinity of gentlemen's seats. They are, as dairy-stock, distinguished for rich rather than for an abundant flow of milk. They do not continue in full profit for the same period as the Ayrshire cow. The calf is generally suckled where extensive herds of West Highlanders are kept. This breed can exist on the coarsest herbage, and maintain its footing where none of the other breeds would be safe.

Orkney cattle are of small size—colours black, or black and white. They are stunted in form, deficient in symmetry, and do not arrive early at maturity. The introduction of Short-horn bulls for crossing the native Orkney cow, will in a short time entirely change the character of the cattle sent from these islands to the mainland. Already the improvement in the stock sent out is very marked.

The Shetland Islands possess the smallest of the British breeds. When fattened, they seldom reach twenty-four stones of fourteen pounds. The colours are varied—brown and white, black and white, yellow, cream-colour, &c. As milkers, the Shetland cow, for the small quantity of food consumed, yields a large quantity of rich milk. The produce of a Shetland cow and Short-horn bull resembles the Short-horn closer than the Shetland; but they are generally disproportioned: they rapidly acquire flesh, and are not so suitable as the pure Shetland for a pet dairy cow. The cattle in Shetland, particularly during winter, resort to the sea-shore to eat sea-weed. They generally leave the mountain pasture for the sea-shore as the tide retires, and are seldom caught by the returning tide, although there have been occasional instances of animals being lost by the tide cutting off their retreat to the shore.

The *Kerry* is the only native Irish breed, and is confined to the western and more mountainous parts of Ireland. They are equally diminutive with the Shetland, are hardy, and can subsist on scanty fare. They are of various colours, but black is the most common in the Improved Kerry. They are well adapted for cottier holders in the mountain districts, yielding a considerable quantity of rich milk.

We have thus briefly treated of the breeds of cattle valuable in Great Britain. The most prominent, in general estimation, is the Short-horn. Of the breeds adapted for the dairy, the Ayrshire is the most esteemed; but the character of the climate, herbage, and local treatment, all influence the question of adaptability of breeds for particular districts or management. There are inferior animals of all breeds; and on fixing upon a breed, it is equally important to study to secure the best specimens, whether the object be for the dairy, or for the production of cattle intended for the shambles.

TREATMENT OF DISEASES.

Cattle are subject to various diseases, the result of improper treatment, or of causes connected with climate, which it is difficult to guard against. Many diseases can be traced to hereditary predisposition, such complaints generally proving the most obstinate to treat. By attention to feeding, shelter, and cleanliness, much can be done to promote a healthy condition. Cattle housed during winter in well-ventilated byres, or in open sheds, and partially sheltered during summer, are usually healthy. Certain breeds are naturally hardy, and can be kept in the open air during the whole, or the greater part, of the year; such cattle are comparatively free of those diseases which are induced by exposure to cold and wet. Cows confined to byres during the whole season, and fed to repletion, to induce an abundant flow of milk, are very liable to diseases of the respiratory organs. Cattle, when being fattened, are also subject to such inflammatory attacks. Veterinary surgeons usually prescribe bleeding and laxative medicines, and occasionally tonics. Recent experience in the treatment of inflammation of the lungs, particularly of pleura-pneumonia, has tended to shake confidence in the curative effects of bleeding—soothing rather than violent treatment being found the most successful. The owners of stock who can obtain, within a convenient distance, the services of an experienced veterinary practitioner, should employ such, rather than attempt to effect cures; but as certain complaints require prompt measures, the owners of cattle should be sufficiently informed, so as to be able to prescribe in such cases. All quacks should be discountenanced, and reliance placed on the curative power of nature rather than on the nostrums of the ignorant. Supernatural influences may tax the pocket of the superstitious, but will not effect cures. For the purpose of guiding the non-professional person, the following concise description of the more common complaints of cattle is given:

Choking.—Cattle fed on bulbous roots, such as turnips or mangold, are liable to accidents from swallowing a portion of a root without its being previously sufficiently masticated to pass down the gullet into the stomach. The animal ceases to eat, and stands apart from the rest of the herd. The distress of the animal, and the danger arising from the impacted substance, are in proportion to its size, form, and position in the

* We are indebted to the *Farmer's Magazine* for this and the Polled Angus Bull.

gullet. When it is fixed near the top of the gullet, the discharge of saliva, with efforts to regurgitate, is considerable. The head is occasionally extended, and the animal coughs frequently. By this, the obstruction is sometimes moved, and relief afforded. When the substance is fixed near to the entrance of the stomach, the discharge of saliva with eructations and coughing is usually absent. In both cases, the breathing and pulse become accelerated, and except the obstruction is displaced, there is considerable danger. The abdomen gradually distends, respiration becomes laboured, the pain increases, and the animal staggers, falls, and is suffocated. To prevent this, means are taken to force the substance downward into the stomach by the use of a probang. This, for an ordinary sized animal, requires to be about six feet in length, elastic, with a cupped knob on the end, somewhat rounded at the edges. If the probang is hollow, it admits of the escape of the gas. To operate, at least two persons are required; one to hold the head of the animal; the other, to pass the probang into the gullet and press the substance into the stomach. Lard, butter, or oil should be rubbed on the point of the probang; the operator taking hold of the probang, the tongue held with the left hand, or the assistant taking the tongue to one side, the probang being passed along the roof of the mouth enters the gullet. As it reaches the impacted body, firm but moderate pressure should be used. In using the probang, the head should be elevated, and kept in a straight line with the neck. When the resistance is great, care should be taken not to force the end of the probang past the obstructing substance, or to injure the gullet. The substance once moved, there is seldom any difficulty in forcing it down into the stomach. As the length from the muzzle to the entrance of the rumen is about six feet, the probang should be passed downward within a few inches of its entire length. Upon displacing the impacted substance, the gases collected, speedily escape, and the swelling falls. Sometimes it is necessary to puncture the rumen, to prevent suffocation. When this is done, the probang seldom requires to be used, as the obstructing body is gradually softened, and afterwards passes into the stomach. There are cases which can be relieved by giving the animal a dose of linseed oil or salt dissolved in water. But this treatment generally causes great pain to the animal, and there is some danger of a portion passing into the windpipe. Neither the probang nor the trocar should be used except there appears to be considerable danger, as there is always a liability to accidents in operating. Animals which have once choked, are liable to become again affected; and for some time they should have the roots grated, or other food substituted.

Hove.—This disease occurs during all periods of the year, but is more common in spring and autumn. *Hove, hoven, swollen, dew-blown, clover-sickness, fog-sickness,* are various terms by which a distended rumen is known. Hove may arise from a rapid swallowing of the food followed by the sudden repletion of the stomach; or it may proceed from a deranged state of the digestive organs. In either case, an evolution of gas takes place, which, if not speedily neutralised, or means used for its liberation, causes death, generally by suffocation. Sudden changes in the diet are liable to cause the disease. In spring, when animals which have been confined to courts or byres, are turned into fields where the herbage is luxuriant, with a considerable portion of clovers, they are liable to swell. The liability is increased when the grass is damp from hoar-frost, dew, mist, or rain; also when there is a breeze more or less strong. In summer and autumn the danger is increased when the cattle are placed upon second-crop clover, or allowed to graze on stubbles, where the young clovers are advanced. Cattle getting into a field of beans or peas when these are in a succulent state of growth, are liable to hove, particularly if the crop is damp. Cows which are removed from their pastures to be milked, are more liable to hove than cattle allowed to remain at pasture. Hove occurs occasionally during winter with cattle being fattened on turnip. Swedes which have been mildewed are very liable to produce this state. Partaking of bean-meal along with turnip generally increases the tendency to hove. The disease is frequently sudden in its attack, requiring to be combated speedily, or the animal may be lost. When the distension is not so far advanced, ammonia in water, or lime-water, should be given. Alcohol has also a good effect. Tar placed in an egg-shell, and passed by the hand over the throat, usually gives relief. One to two ounces of turpentine added to a quart-bottle of linseed oil generally reduces the swelling. One ounce of hartshorn, with four drachms of powdered ginger in a pint of water, may be given, or two drachms of chloride of lime dissolved in a pint of water. If the distension is so far advanced that the animal is suffering considerable pain, and moves with difficulty, an incision into the rumen should be at once made, if relief is not afforded by medicine. The delay of a few minutes may prove fatal. An incision made with a sharp-pointed penknife, or with a trocar, will give speedy relief—the instrument passed inward and downward to puncture the rumen. If a knife is used, a quill may be inserted in the wound. It is all-important to remember that the incision should be made on the left side, in that part of the abdominal cavity between the last rib and the point of the hook-bone. After the escape of the gas, the wound may be drawn together by a needle and thread, or piece of sticking-plaster placed on the part. The feeding afterwards should be restricted in quantity. If the patient exhibit symptoms of constitutional disturbance, aperient medicine may be given. One pound of common salt, or an equal quantity of Epsom salts dissolved in water, is the most suitable.

Abortion occurs more frequently in the cow than in any of the other domesticated animals. When one cow of a herd aborts, the case is usually followed by others; and the cow which has once slipped calf, is extremely liable to subsequent abortion at the same period of gestation. The character of the food (such as pastures or forage affected with ergot), fright, violent exertion (as in leaping fences), disease such as pleura-pneumonia, and other causes, tend to produce abortion. When it takes place at the early stages of gestation, the constitutional disturbance is seldom great. Occurring, however, after the fifth month, there is considerable danger from inflammation, particularly of the womb. It is advisable to give sedative medicine: the best is common salt in the drink of meal-gruel. The food should be restricted, and the cow kept quiet, being previously removed to a comfortable loose house, and away from the other cows. Unless the animal is valuable for breeding purposes, it is advisable to fatten her off. If, however, it is determined to retain her, she should be got into good health previous to being served; and after she is pregnant, she should be kept quiet, fed regularly, but rather sparingly. Some practitioners recommend that within a few days of the period of the former abortion, four quarts of blood should be taken from the neck, and one ounce of the tincture of opium given each alternate day for a week. Keeping the animal in an open shed, and studying quietness, is the best security that the cow will reach the full time.

Puerperal fever occurs frequently where the cow is in high condition, the flow of the lactic fluid considerable, and where parturition has been protracted and severe; but very frequently it arises from overfeeding previous to and after parturition. The cow, when affected, rises with difficulty—sometimes is unable to get up—the flow of milk is nearly, if not wholly suspended; and if relief is not speedily afforded, the animal dies. The first duty of the practitioner is to act upon the bowels—one pound of Epsom salts, with

two ounces of ginger, dissolved in water, should be given. This may be repeated in four hours. Clysters may also be tried. The udder should be bathed, and every effort made to induce a flow of milk. No time should be lost in calling in the most skilled practitioner.

Garrot in the udder sometimes follows severe parturition. It is, however, more frequently produced by an excessive flow of the lactic fluid to the udder previous to calving. It also arises from an unskilled or careless milker not drawing the teats regularly, nor emptying them completely. If the udder is much distended previous to parturition, the cow should be milked, and this for several days. Not only is this a great relief, but it tends to check that febrile condition incident to the constitutional disturbance. The indications of garrot are, a hot udder followed by a hard knot, after which pus and blood are mixed with the milk—this generally from one teat. Occasionally an abscess forms on the outside. Upon the first symptoms being observed, the cow should receive a handful of salt in gruel or in boiled food; repeat it every time the cow is fed till the bowels are acted on—the quantity of food restricted. The udder should be bathed with hot water, and gently rubbed, and the teats emptied. A little lard rubbed over the udder is also advisable. This should be attended to each time the cow is milked—three times in the twenty-four hours. If the garrot proceeds to form pus, the affected teat should be drawn regularly, and the matter coming from the teat kept separate from the rest of the milk. The endeavour should be to preserve the teat, by preventing it closing up. A cow with a light or blind teat cannot be disposed of as a sound animal, although the quantity of milk is seldom much impaired. When two quarters of the udder are affected, the result is different.

Diseases of the skin are not common in cattle that receive ordinary attention as to housing, cleaning, and feeding. *Mange* is produced either by contagion or by poverty of condition, arising from neglect. A mixture of oil and sulphur should be well rubbed into the roots of the hair. The animal should receive one pound of common salt each alternate day till the bowels are operated upon—bran mashes, roots, or green food allowed. As the disease is contagious, the patient should be separated from other cattle. *Lice* is a much more common complaint than mange; indeed, these parasites are seldom absent from cattle kept in byres or open sheds during winter and spring. Contact, direct or indirect, with animals affected, inattention to cleanliness in byres and cattle-courts, and, some believe, exposure to wet, with low diet, cause the presence of lice in cattle of all ages. Several recipes are in use; tobacco-juice, with spirit of tar, is the most common; a salve composed of mercury and lard; also soft soap and oil mixed with sulphur. Oil well rubbed into the roots of the hair, where the larvæ or lice appear, is the best treatment. The oil closes the breathing organs of the parasites, and thus speedily kills them. The skin should be well curried, and the parts to which oil has been applied may be washed with soft soap and water, followed by rubbing with dry wisps. The byre or sheds should be gone over with lime-water, to destroy any of the larvæ in the wood-work or stone walls.

Red-water occurs frequently during spring and towards the end of autumn among cattle grazed on low damp situations, subject to hoar-frost. It also occurs during summer, when the season is dry, with heat and cold alternating. The disease is confined chiefly to young animals, or cows that have recently calved. Red-water has been attributed to sudden chills; the animal exposed to the sun's rays during the day, lies all night on cold ground, while the temperature falls below the freezing-point. The disease is connected with a deranged state of the digestive organs, principally of the liver. The first symptom is diarrhœa, with loss of rumination; this is followed by constipation; the fæces also become black, and the animal rapidly loses condition; and if in milk, the secretion almost wholly ceases. The disease should be treated with calomel. The following may be given in oatmeal gruel: Calomel, one and a half scruples; carbonate of ammonia, four drachms; sulphur, six ounces; sulphate of magnesia, six ounces. After the animal is convalescent, exposure to cold or extreme heat should be avoided.

Chronic diarrhœa is common to cows that have been improperly managed when young; it is also hereditary. The disease is generally, however, the reiterated application of causes seldom suspected at the time, till the constitutional disturbance shews itself. The animal loses condition. Diarrhœa is frequently the concomitant of other diseases, consumption being the most common. With cows turned out daily during early spring, or kept late in the season at pasture, receiving little house-feeding, the scanty fare in the fields, with the cold and wet, causes diarrhœa. The local terms of *wasting*, *consumption*, *rot*, *scouring*, &c., all indicate a state of disease, which, if not checked, ultimately causes death. In dairy districts, the complaint occasionally carries off a great number of cows. Calves are also subject to scour, arising from a derangement of the stomach. Carbonate of magnesia, two drachms, may be given to a calf: for cows and young cattle—calomel, two scruples; opium-powder, half a drachm; chalk, three ounces, mixed in gruel. It is sometimes advisable to empty the intestines by a dose of salts. Half a pound of Epsom salts may be given—this followed by calomel and opium, half a drachm of each given daily.

Quarter-ill, *black-leg*, *felon*, *shewt of blood*, &c., are local names for a disease of an inflammatory nature, to which young cattle are exceedingly disposed, unless their condition is kept up and their comfort otherwise studied. Sudden in its attack, and rapid in its progress, generally terminating fatally, all that can be successfully attempted is *prevention*. The animal is observed to be lame; the affected limb when examined is found swollen; the skin over the part, when pressed, gives a crackling noise; exudated bloody serum is collecting in the cellular tissue. The inflammation proceeds; mortification ultimately ensues; and the animal usually dies within a few hours after being observed to be unwell. Calves weaned and kept late in the season at pasture, in fields exposed to the prevailing winds or to the miasma of a marsh or damp ground, with the herbage hard and deficient in nutriment, are extremely liable to become affected, either during the period or within some months after they are removed. When the disease appears after the removal, the feeding has usually been improved in quality. A sudden change in the flow of blood causes a febrile condition, followed by congestion in one or other of the limbs—in some cases, in the brisket. An extrication of gas, followed by serum, in the cellular membrane, and, if the animal survives, extensive sloughing of the skin, take place; but sloughing is so exceptional, that few practitioners have witnessed a cure. When one animal of a herd becomes affected, the patient, as well as the remainder, should be bled; the intestines relieved by a dose of salts, from one quarter to one pound of Epsom salts or common salts. With those not affected, the supply of food should be regulated so as to prevent a rapid formation of blood, because the weakened condition of the system is unequal to carry on a rapid organisation of the frame. The bowels should be kept in a healthy state: to secure this, allow oil-cake from two to five pounds daily. The disease is confined to young animals; and is rarely known to attack those which have reached two years.

Catarrh, *cold*, *cough*, is often induced by exposure to cold and wet, occurring mostly in spring, when the wind is easterly. Inflammation of the mucous membrane of the air-passages which line the nostrils, causes a slight cough; the throat is usually affected, the coat staring. If the cough is short, husky, and dry, and the animal

looks anxious and haggard, the inflammation has extended to the lungs; bronchitis is present, a dangerous disease, requiring the aid of the most skilful veterinary surgeon. Catarrh is not unfrequently manifested as epizootic. Fever is invariably present, but not always of the same character; sometimes of a low typhoid kind; in other cases, active. When one animal of a herd becomes affected, it should be separated, being placed in a warm but well-aired house; bleeding, with aperients and counter-irritation, employed. Those not apparently affected, should receive a dose of common salt, the throat being rubbed with a stimulating liniment. Cake should be allowed; if previously given, the quantity should be increased, and the animals protected from cold, and especially from wet. If they are confined to an ill-ventilated byre, a portion should be removed to another place, the ventilation improved, and cleanliness strictly carried out. The disease is so subtile, that unless the greatest care is taken, a portion may be expected to succumb. Some practitioners insert a seton in the dewlap as a preventive of this as well as of quatrer-ill.

When *inflammation of the lungs* sets in, there is quick and laborious breathing, occasionally accompanied with a low noise; cough, short and painful; the pulse is sometimes full and strong, but is frequently weak; the nostrils are dry and red, the mouth hot, the eye dull; the skin is cold to the feel, and the hair partially staring. The rumination almost wholly ceases; condition is rapidly lost; and except the disease is checked, the animal, gradually becoming weaker, dies. Bleeding in the earlier stage, the bowels opened and kept active, counter-irritants applied to the sides immediately behind the armpits, are the only means at command, but they seldom prove successful in the treatment of cattle. The most insidious, and, at the same time, the most extensively fatal form of inflammation of the lungs, is

Pleuro-pneumonia.—There has been difficulty in tracing this epizootic pestilence. It was first experienced in England in 1842, and in Ireland at least a twelvemonth previously. Introduced, it is stated, from the latter to England by a lot of half-starved cattle, the disease rapidly spread over several of the dairy counties —Cheshire, Shropshire, Staffordshire, and Middlesex suffering most. Since that period, the annual loss from the disease exceeds perhaps any estimate that has been made. Its ravages have been most extensive in ill-ventilated, crowded cow-houses. Town-dairies suffer most severely, pleuro-pneumonia sweeping off in a few months almost the entire stock—sometimes absent for weeks, and returning with aggravated symptoms. In rural districts, the disease may be found on one farm, those in the neighbourhood being free. Frequently, however, these are afterwards affected, although there are farm-places, and even districts, where the disease has never appeared. Professional opinion is divided as to its contagious or non-contagious character. Farmers, however, generally believe that it is contagious, and strong evidence has been adduced in support of this belief. The virulence is known to increase with the absence of cleanliness and with over-crowding, especially in swampy and marshy districts. The disease is seldom observed by those in attendance on the stock till it has reached the second stage. The earlier symptoms are a slight cough, breathing laboured, the coat staring, and dulness, with general depression. These tokens frequently depart for a time, returning generally in a few days with increased force. The breathing is then accelerated, the cough becomes more painful, the animal moves unwillingly, looks dull, the eye anxious, the appetite and rumination impaired. In the third stage, rumination is suspended, respiration short and catching, the belly tucked up, the cough still more husky and painful; the anxious expression is followed by the eye becoming glassy; condition is rapidly lost; the animal breathes with difficulty, and dies from suffocation, or from general prostration.

Various remedies have been tried to combat the disease; bleeding was at first recommended as the sheet-anchor. When bleeding was practised at the second stage of the complaint, it was observed rather to hasten than to retard the crisis. Inoculation, as a means of prevention, was much lauded for a time, and its efficacy is still believed in by owners of stock in Holland, Belgium, and parts of France. In England, it never found many advocates. Arsenic and other powerful medicines have been all recommended, experimented with, and found inefficient. The general practice is now, both with cows and feeding-stock, upon the first appearance of the disease, to dispose of them for slaughter. Sometimes, however, treatment is attempted, but generally with little success. If the disease is observed in the first stage, blood should be taken, the throat rubbed with a blistering liniment, the bowels acted on by salt, and green food should be given. The febrile symptoms checked, tonics, sulphate of iron with manganese, should be given, a small portion of nitrate of potash added, and the animal kept in a well-ventilated place, all draughts being avoided. If the patient is a cow in milk, convalescence is more doubtful, this disease being extremely fatal with dairy-stock, particularly those in full vascular condition. If the disease has reached the second stage, bleeding is seldom advisable; dependence should rather be placed on acting on the system through the bowels, and by keeping up the system by giving sedative medicine, nitrate of potash, tartarised antimony; also tonics, drinks, and green food, the blood being kept to the surface by gentle friction of the skin and sheeting. Abortion generally follows this second stage, and the cow sometimes recovers almost immediately after the fetus is expelled. If recovery follows, the condition of the cow should be advanced previous to the service of the bull, and the after-health of the animal studied. The disease will have destroyed a portion of the respiratory powers of the animal, and, except she is very valuable for breeding, she should be fattened and disposed of to the butcher. An animal which has suffered from a pulmonary affection should not be fed on forcing food, whether for fattening off, or retaining as a breeding or dairy animal, as there is some danger of the disease being again developed. Indeed, the greatest care is required to avoid a new outbreak. Cold, damp, and foggy weather, particularly with occasional gales, appears to hasten the development, if not the generation of the disease. As the disease is both epidemic and contagious, the employment of every precautionary measure is the more necessary.

Excrema, fever in the feet, foot disease, mouth disease, vesicular epizootic, epidemic, &c., are terms for a disease which is highly contagious, as well as epidemic. It spreads rapidly through the whole herd, and may be communicated to animals of a different species—sheep, pigs, poultry, &c. This complaint was unknown in Great Britain previous to 1839. The first symptoms are a cold shivering fit, the body trembling and parts quivering; the whole being cold, especially the extremities. There is a discharge of frothy saliva from the mouth; food is refused, and rumination is suspended. The cold is followed by reaction; the extremities become hot; the muzzle dry; the mouth, hot and sore; tongue, swollen; vesicles appear on the tongue, lips, and other parts of the mouth. The animal becomes restless, sometimes shaking the legs with violence. The hoofs suppurate; blisters form at the union of hair and hoof, and between the toes, and pus is sometimes discharged from the openings. The animal becomes very lame, walking with difficulty, and placing the heels first on the ground. The disease usually runs its course in seven to fourteen days, terminating favourably. There are cases, however, when the animal is unable to rise, and there is a general prostration of strength; and except the animal is nursed, and care otherwise taken, death follows. The general treatment

should consist of a dose of salts, one pound; sulphur, four ounces. The feet should be bathed, and if the animal is down, they should be poulticed, and the hoofs pared close. If blood exudes from the toes, the recovery will be more speedy. Dress afterwards with an astringent lotion; and if proud flesh appears, a stronger caustic must be used. The laxative medicine should be followed by tonics—sulphate of iron, two drachms; ginger, two drachms, given daily. Oatmeal gruel, given by a horn, if the animal will not drink—poured down the throat not less than three times daily—and green food or sliced roots offered. Every means should be used to keep up the system, as the disease is generally accompanied by great prostration. Upon the first appearance of the disease, it was regarded with great alarm—stock lost condition; and where care was not taken, death occurred. The disease is now much more mild, less frequent, and is not a cause of much anxiety.

Murrain, steppe-murrain, rinderpest, pest bovine, typhoid bovine, &c., are various names for the same disease. In the steppes of Southern Russia, and in parts of Austria, the disease, it is stated, is constantly present, extending occasionally into other districts, communicated by affected animals travelling northward and westward from the breeding districts. The number of animals which have died from this disease during periodic outbreaks is almost fabulous. In Russia and Austria, prompt measures are now taken to prevent the spread of the disease; not only the affected animals, but all cattle they come in contact with, being destroyed. It is supposed by the best informed German and French veterinary authorities, that, by adopting the measures used in those districts where the disease is constantly prevalent—namely, slaughtering all affected animals, and indemnifying the owners—the disease could in a short time be wholly eradicated. This, or a disease similar in its character, called the murrain, was experienced in the British Islands during the latter half of the last century. It appeared first about the year 1745, and continued its ravages for several years; in many parishes, nearly the whole cattle were swept off. In the early months of 1857, considerable alarm was felt lest the steppe-murrain of the continent should be introduced into this country by animals from the Baltic ports. To guard against its introduction, an Order in Council, prohibiting the importation of cattle, hides, &c., from certain of the Baltic ports, was issued. Recent information shewed that the alarm was caused by exaggerated reports of the condition of the cattle in parts of Prussian Poland. The prompt measures adopted in Prussia have prevented the disease spreading. The diseased animals were destroyed, and a military cordon established, preventing all communication with the affected districts.

There are several other diseases to which cattle are subject, but as they are exceptional rather than common, a description is not deemed necessary. Consumption, chronic dysentery, tumours, with tendency to catarrh and scrofulous complaints, are indications of a constitutional predisposition, which unfits the animals for breeding purposes, and also for the dairy, particularly where the milk is used as food.

FATTENING FOR MARKET.

Rules for Selecting Cattle.

In selecting cattle for *feeding*, the first point is to fix upon the breed suitable for the character of the accommodation, and for the food intended to be supplied—also, whether for winter or summer feeding. The next consideration is the age, and certain indications as to the fattening qualities of individual specimens or lots: those animals whose forms are symmetrical, having the back straight, ribs well-arched, chest deep and full forward between the fore-legs, quarters long and broad, legs rather short than long, the joints being large, fatten rapidly. But the most certain indication of a quick feeder is the touch—a soft, mellow, vascular skin with a covering of silky hair. The character of the horns, when these are present, also indicates the feeding qualities. The horn differs in the sexes, castration producing a great change in its form. In all cases, the horns should be placed wide rather than close, growing outward and forward.

To judge of the age of cattle by outward signs, considerable experience is necessary. The dentition is the most certain guide; still, there are considerable variations, due in some measure to such causes as feeding and the peculiar breed. Professor Simonds has found, from a long series of observations, that the following are the averages of the appearance of the incisor teeth:

Average of Early Dentition.		Average of Late Dentition.	
1 year 9 months	to	2 y. 3 m.	Two permanent incisors.
2 years 3 "	"	2 " 9 "	Four " "
2 " 9 "	"	3 " 3 "	Six " "
3 " 3 "	"	3 " 9 "	Eight " "

The dentition is completed about the fourth year; consequently, a four-year old animal will be full mouthed. The incisors, as they flatten and wear on the surface with a diminution of size, indicate the age—the incisors which first appeared changing first, and being followed by the second, third, and fourth pair of incisors. The horns also indicate age, rings appearing each spring. The first ring appears at three, sometimes, however, at two years, particularly in the female which has produced. In the market for dairy-stock, the use of the file and sand-paper is sometimes traceable on the horns of middle-aged cows.

Methods of Housing and Feeding.

Cattle are fattened for market by several methods. Besides grazing in the fields during the season of grass, they are fattened in courts or boxes, receiving regular supplies of green food—grass, tares, &c. Usually, cake and corn are given as auxiliaries. During winter and spring, cattle are prepared for market in open sheds, loose boxes, and byres—fed upon hay, roots, cake, and corn. Consuming turnip in the field by cattle is now seldom practised. Summer-feeding in sheds, loose boxes, and byres, has been much advocated; but the system does not gain ground rapidly. Cattle placed on permanent pasture producing rich herbage, make greater and more uniform progress than cattle confined to courts, boxes, or byres. There is always considerable difficulty experienced in obtaining a regular supply of succulent food; and unless cake, or cake and corn, are given, cattle do not fatten rapidly in confinement. On arable farms, without any portion in permanent pasture for cattle, soiling presents many advantages. By cutting the mixed grasses for feeding cattle, a greater number can be kept on a given space, the manure-heap is increased, and the after-crops, where the grasses have been cut, are superior. To carry out the system successfully, a supply of tares, if not of lucerne and sainfoin, is advisable; also water at command, regular feeding as to time and quantity, and increased allowance of concentrated food—such as cake—as the animals improve in condition. For calves, year-old cattle, and other animals not being prepared immediately for the fat market, soiling is advisable, combining economy of food with protection from exposure to sudden atmospheric changes. To secure the full advantages of soiling, good ventilation, cleanliness, quiet, and regularity in feeding, are indispensable.

It is in the winter-feeding of cattle that the greatest difference of opinion exists among practical men, both as to the mode of housing and the manner of feeding.

Fold-yards with sheds is the most common method of housing. When these are constructed so as to divide the cattle into small lots, and the shedding is ample and comfortable, cattle are found to make equal progress with those confined in byres or loose boxes, provided

the climate is not severe. Where the rain-fall is excessive, and where the cold, either from altitude, exposure, or latitude, is considerable, cattle make greater progress confined in byres or in loose boxes.

Stall-feeding is the common term where the animals are fastened up in stalls or tied to stakes. From the restraint preventing exercise, young cattle, one and two year-olds, generally suffer from diseases of the joints after they have been kept in one position for two to four months. When the knee and hock joints become inflamed and swollen, further progress is arrested, and the animal requires to be placed in a loose box or open shed, to recover. If the removal takes place upon the first appearance of joint disease, the rate of progress is little checked; but when delayed for one month or more, the animal seldom recovers so as to repay the value of the food consumed in fattening. The advantages of stall-feeding consist in the economy of house accommodation and of food, and in the equal distribution that it secures of concentrated feeding-substances.

Box-feeding has lately been much advocated. When the boxes are properly constructed, and the comfort of the animals otherwise studied, this system presents, on the whole, advantages which neither of the more common methods possesses. The cattle are placed either singly or in pairs. When single, the divisions are usually spars, to admit of the animals seeing one another. Spars being more economical than walls of stone or brick, are the more common division, even when two or more cattle are placed together. The advocates of box-feeding assert, that besides the warmth and shelter provided without the restraint of the stall, there is economy of straw used for litter; and the manure is very superior to that produced in open courts or from byres.

Board-feeding has also been advocated by Mr Mechi and others. But cattle kept on sparred boards do not advance in the same ratio as cattle kept in loose boxes or open sheds, with their comfort secured by well-littered beds—the feeding and other conditions being similar.

The methods of feeding present even greater diversities than the systems of housing. In England, the practice is rather to restrict the consumption of roots; while in Scotland, turnips are given without stint. In the former, hay is the usual fodder; in the latter, straw.' Without pursuing the difference in practice further, the following are the outlines of the more common methods of feeding:

In England, cattle, which are well advanced in condition on grass by the end of autumn, are removed to the farm-offices, the period of housing being in part determined by the condition of the grass. Hay is placed before them, and a limited allowance of tares, second-crop clover, or turnip, is given. Cake is also furnished. If the cattle are intended for sale in the Christmas markets, the allowance of cake is large—six to fifteen pounds daily are common, particularly for large cattle of the Short-horn, Hereford, or Devon breeds. Cattle not advanced in condition are kept longer in the field. When removed to *hammels*, fold-yards, byres, or boxes, the feeding for some weeks consists of hay with roots, generally turnips of the soft varieties. Sometimes the roots are given whole, but the more general practice is to cut or to slice them. For this purpose, several implements and machines are in use. Latterly, machines for pulping the roots have come into considerable request. The most recent and most highly approved system of preparing the food, is to cut the fodder—a mixture of hay and straw—and to reduce the roots by a pulping-machine. The cut fodder and the pulped roots are mixed together, and afterwards given to the stock. Some feeders advocate that the mixture should be allowed to lie in a heap for some hours before it is put into the feeding-troughs. Besides the mixture of fodder and roots, the adding of dissolved linseed or cake, made into a jelly, is practised, and with the best results. The economy of roots is so considerable that the consumption is reduced to fully one-half; and the progress obtained is the maximum.

The most general practice is to house cattle in October, and to commence feeding with the softer varieties of turnip; these, continued up till the month of January, are followed by Swedes or mangel-wurzel. Cake or corn is allowed; sometimes a mixture of the meal of barley and beans is given along with oil-cake, equal weights of each. As the condition of the animals advances, the allowance of cake, corn, &c., is increased. Commencing with three pounds, the allowance is augmented to ten pounds daily.

The quantity of roots an ox will consume depends in some measure on the age, condition, and size of the animal, but especially upon the quantity of auxiliary feeding-substances given along with the roots. An ox which, when fattened, will weigh 60 stones of 14 pounds, will, with straw as fodder, consume of white turnip, 160 to 180 pounds daily; of Swedes, 120 to 160 pounds; of mangel-wurzel, 100 to 140 pounds. When the roots are reduced to thin slices, or are pulped, and then mixed with chopped forage, the consumption of roots will diminish about 25 to 40 per cent. When the allowance of concentrated feeding-substances amounts to five pounds daily, the reduction in the weight of roots is about 10 per cent. With auxiliaries to the weight of ten pounds daily, the quantity of roots eaten is reduced by 30 to 50 per cent., when cake and cut forage are allowed.

With hay as forage, the consumption of roots is rather less than when straw is given; but as hay and straw both differ so much in quality, the relative proportions and the relative influences differ considerably. Some assert that turnips are the cheapest of fattening substances, the quantity being unrestricted, and straw allowed as fodder; on the other hand, there are others who maintain that cattle cannot be fattened on turnip and straw, and that it is economical, both as to time and the consumption of roots, to give hay, with cake and corn in addition. Present practice, influenced in part by the high rates for beef, is to allow a certain quantity of cake, corn, or a mixture of both; the roots sliced or otherwise prepared, the cake broken, and the corn ground into meal. As previously stated, the practice of the English feeder is to use hay as fodder; of the Scottish feeder, to give straw only as fodder, along with roots. Both fatten cattle at nearly the same rate of advance, which is, on an average, about two pounds of live weight daily. This is taken to represent the increase in beef. When auxiliary substances are given, the rate of progress reaches about three pounds daily of live weight. In Scotland, the usual estimated period of fattening an ox is five months; this period is shortened by the employment of auxiliaries—cake, corn, &c. In England, the period of fattening is somewhat longer; but the English feeder prefers to mature the cattle more perfectly than the Scottish feeder usually does.

DAIRY HUSBANDRY.

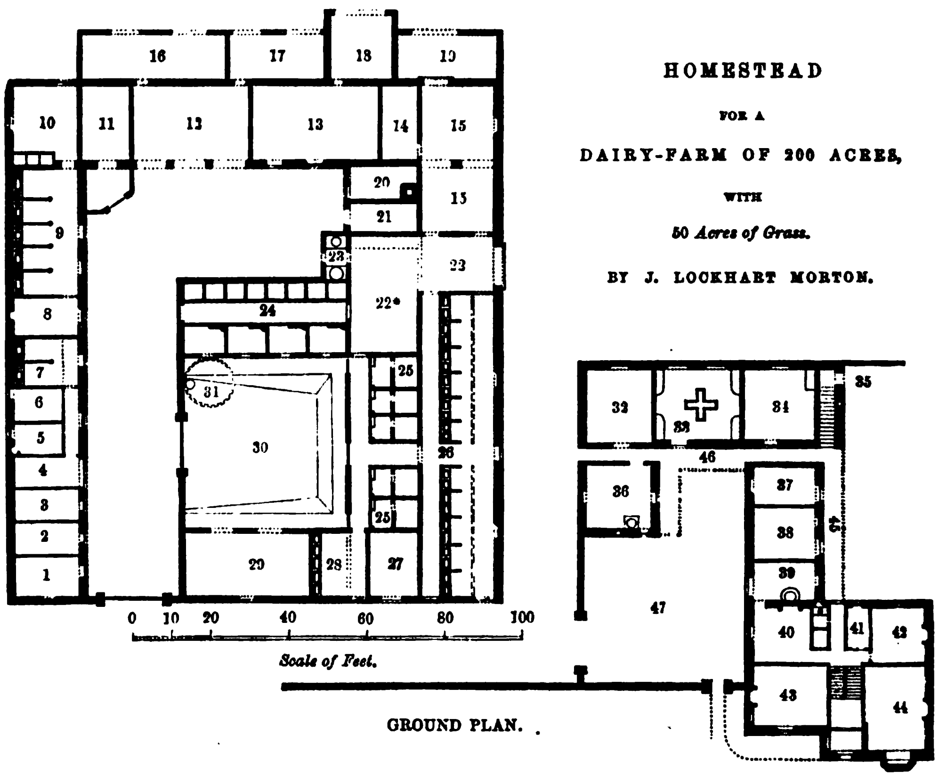
Dairy husbandry is generally practised in low-lying districts, with an argillaceous soil, producing nutritious herbage. Occasionally, dairy-farming, combining the rearing of cattle, is followed in upland and moorish districts, unsuitable for sheep or for arable husbandry, and the fattening of stock. Dairy-farms in England are most frequently to be met with in Cheshire, Gloucestershire, Wiltshire, Lancashire, Leicestershire, and the counties of Devon and Somerset; in Scotland, in the counties of Ayr, Renfrew, Lanark, Dumbarton, Stirling, Linlithgow, Wigton, and Kirkcudbright. In Ireland, the best dairy-farms are to be met with in the southern counties, the best quality of butter being shipped at Cork.

A well-arranged homestead, having every convenience to accommodate the cattle, and to store and prepare their food, is of essential importance in a dairy-farm. In the annexed figure, we give the ground-plan of one adapted for a farm of 250 acres, designed by J. Lockhart Morton, 26 Parliament Street, Westminster. The external view is given in our frontispiece.

An excellent arrangement for a dairy-farm steading will be found in Mr Stephens's elaborate work, *The Book of the Farm*, vol. ii., p. 289.* This plan was carried out in practice, and was found to possess all desirable conveniences.

Cow-houses—Cleaning.

Cows cannot be profitably maintained unless they are treated carefully, and their comfort secured as to house accommodation, feeding, and cleanliness. They should be kept during winter in roomy, well-ventilated byres; and in summer they should be protected against cold, damp, and heat. To secure these conditions, the byre should be occupied part of the twenty-four hours during all seasons of the year. The cows should be kept as free as possible from all extraneous annoyance; as flies, skin-irritation, &c. Many of the points to be attended to in the construction of stables (see No. 38, The Horse), are of equal importance in that of cow-houses; damp should be prevented, and a good healthy atmosphere secured.



HOMESTEAD FOR A DAIRY-FARM OF 200 ACRES, WITH *50 Acres of Grass.* BY J. LOCKHART MORTON.

GROUND PLAN.

Reference Nos. of Open-courted Farmstead.

1. Tool-house, 17 ft. 6 in. by 11 ft. 3 in. 2. Infirmary, 17 ft. 6 in. by 8 ft. 3 in. 3. Ditto, 17 ft. 6 in. by 8 ft. 4. Gig-house, 17 ft. 6 in. by 7 ft. 3 in. 5. Harness-room, 12 ft. 8 in. by 8 ft. 2 in. 6. Hay-house, 12 ft. 8 in. by 8 ft. 2 in. 7. Riding Horses' Stable, 17 ft. 6 in. by 12 ft. 8. Harness-room, 17 ft. 6 in. by 10 ft. 9. Work Horses' Stable, 17 ft. 6 in. by 31 ft. 10. Hay-house, 17 ft. 6 in. by 19 ft. 8 in. 11. Colt-house, 19 ft. 8 in. by 11 ft. 6 in. 12. Cart-shed, 19 ft. 8 in. by 30 ft. 13. Dressing-barn, 19 ft. 8 in. by 31 ft. 8 in. 14. Chaff-house, 19 ft. 8 in. by 10 ft. 3 in. 15. Straw-barn, 18 ft. 4 in. by 37 ft. 6 in. 16. Implement-shed, 35 ft. 8 in. by 11 ft. 4 in. 17. Saw-mill Shed, 25 ft. by 11 ft. 4 in. 18. Stack-house, 16 ft. by 16 ft. 3 in. 19. Straw-shed, 25 ft. 6 in. by 11 ft. 4 in. 20. Engine-room, 17 ft. 6 in. by 8 ft. 6 in. 21. Engine-boiler House, 17 ft. 6 in. by 7 ft. 2 in. 22. Forage-house, 18 ft. 4 in. by 14 ft. 22*. Ditto, 31 ft. by 17 ft. 6 in. 23. Boiler-shed, 12 ft. 2 in. by 5 ft. 4 in., with steaming apparatus, as shewn by dotted line. 24. Box Feeding-house, 41 ft. 10 in. by 18 ft. 4 in. There are eight calf-boxes in this house, with four feeding-boxes opposite. 25. Piggeries. 26. Cow-house, 77 ft. 2 in. by 18 ft. 4 in. 27. Portable Manure-house, 17 ft. by 12 ft. 10 in. 28. Spare Cow-house, 17 ft. by 14 ft. 29. Cattle-shed, 32 ft. 2 in. by 17 ft. 30. Manure Court, 41 ft. 9 in. by 41 ft. 9 in. 31. Liquid Manure-tank, 8 ft. in diameter. 32. Churning-house. 33. Milk-room, with cooler in the centre. 34. Cheesemaking-house. 35. Firing-place. 36. Wash-house for utensils. 37. Potatoes. 38. Washing-house. 39. Scullery. 40. Kitchen. 41. Larder. 42. Bed-room. 43. Parlour. 44. Dining-room. 45. Covered-way communicating between back-door of dwelling-house and cow-house. 46. Verandah. 47. Dairy and Kitchen Court.

Single stalls are preferable in almost every point of view to double. The cows are more easily milked, and not so troublesome or restive as when confined with a neighbour. The division between the stalls—or the *travis*, as it is termed—should be of wood; but stone is commonly used in Scotland. In the majority of byres, travises are absent, the cows being tied to a stake—a round post of wood fixed in the ground at the one end, and above to a wooden beam, which passes the whole length of the byre, with the ends built into the walls. For floors, see our remarks on stables in the number on The Horse. The manger should not, as is frequently the case, be on a level with the floor.

There are various ways of binding or fastening cows to the stall. The *baikie* is objectionable, as it only allows of one position being maintained. The seal is

* Blackwood and Sons, Edinburgh and London.

said to be the best. This consists of a chain or ligature provided with a hook and clasp for retaining it round the neck of the cow; the other end terminates in a ring, which is allowed to slide up and down a post placed in an inclined position at the head of the stall. The lower part of the window should be made of two shutters, the upper part glazed. Where a number of cows are kept, the *byre* or *shippen* should have a central passage, the stalls being arranged right and left of this, with smaller passages between the rows of stalls. In this way, the cows lie in the direction of the central passage, and at right angles to the smaller passages. The cows lie tail to tail, so that the dung from the cattle of the two rows of stalls is easily removed. In some byres, there is a passage in front of the cows, affording facilities for feeding, &c. In a few instances, the byres are so arranged, that the cows stand with their heads to one another, a passage between them admitting of feeding. This form is common in districts of Holland. The root-house should be at one end of the byre.

GENERAL MANAGEMENT.

Dairy-stock.—To insure the perpetuation of valuable qualities in cows intended for the dairy, it is necessary to breed from good bulls of a variety similar to the cows. Cross-bred animals are frequently good milkers, but it is not deemed advisable to continue to breed from such. As the form of the milk-vessel and the milking qualities descend from the sire rather than from the dam, it is important to select bulls of good parentage on both sides. The heifer, if properly fed, should begin to breed at two, or not beyond three years old; the cow is at her prime at from four to seven years, and falls off by nine to twelve years, at which age it is customary to fatten her for market. In selecting cows for a large dairy for supplying milk for town-consumption,* a preference is usually given to cows that have had their third or fourth calf. The period of service of the bull varies considerably; breed, mode of feeding, &c., all influence the time a bull can be kept for service. In the more highly improved breeds, such as the Short-horn, one year-old bulls are preferred by some. Occasionally, superior animals are kept till twelve years. In ordinary breeds, such as the Ayrshire, Polled, and Highland breeds, the bulls are reserved till they reach two years, and retained till the age of four, or seven years.

The period of gestation in the cow is liable to very considerable variation; the average period is about nine months two weeks. A calf is most likely to survive and be healthy which has been carried the full time. Calves have survived that were born in the seventh month, also those that were calved in the eleventh month. Heifers come into season generally when about fifteen months old; there are instances of Short-horn heifers being impregnated at seven months. The age at which they take the bull is regulated by the breed, and in a special manner by the food. Heifers and cows come into season at different periods of the year; but spring, summer, and autumn are the more common periods. The cow remains in season about twenty hours. The periodic return is from three to four weeks, except she is impregnated. Once impregnated, the desire ceases, if the animal is in health. After parturition, the cow, if highly fed, will come into season in three weeks; with ordinary keep, the period may be six or more weeks. Under a very low diet, or in low condition from disease, the cow does not come into season till the flow of milk is considerably diminished. In the Shetland Islands, to be in calf one season, and to be farrow next, is not an uncommon occurrence.

The period during which a cow will yield milk depends, in some measure, on the feeding. If not in calf, the flow of milk may be kept up for several months beyond the average period, which is nine to ten months. There have been instances of cows milking well the second season, and falling little short in quantity of those having had calves; but these cases are exceptional. Heifers that had never been impregnated have yielded milk in a moderate quantity, while in very exceptional instances the flow has been considerable; but, as a rule, the secretion of the lactic fluid is most abundant when the animal has produced a calf at the usual period of gestation, the calf being pure, not cross. The sex of the calf has been supposed to influence the amount of the secretion: with a bull-calf, the quantity, it is generally believed, is greatest.

The cow may be kept in milk up to within a month of the period of calving, but should be allowed to get gradually dry from six to twelve weeks previous to the expected period of parturition. In dairies where cows are kept for supplying towns with milk, it is customary to fatten the cows. The animals are supplied with highly nutritious food, the secretion of milk being kept up by every means, till the falling-off is so considerable, as to render it more profitable to supply her place with another cow about to produce, or one which has recently produced. The cow is sometimes dried in the dairy, and fattened off; the more common practice, however, where the food is purchased, is to part with the cow in a half-fattened state. In dairies where the produce is manufactured into butter or cheese, the practice is to keep the same cows, parting with them only when, from age or other causes, they are unsuitable for producing the average maximum of milk. On breeding-farms where the calf follows the dam, the cows are usually sold at six or seven years, their place being supplied by young heifers.

Calving.—When in a state of health, no difficulty will occur at the parturition. The cow should be kept quiet, and no assistance given except in difficult cases. A shepherd, or one familiar with stock, may assist, particularly if there is a false or wrong presentation; but the more prudent course in difficult cases is to summon the veterinary surgeon. After parturition, the calf should be removed, rubbed, and partially covered with straw. Some prefer to place the calf before the cow, sprinkling salt over the calf. Most dairy-maids also throw a portion over the loins of the cow! The calf is removed after it has been gone over by the tongue of the cow, and is either placed in a house away from the byre, or it is tied up behind the cow in the byre. The suckling of the calf is gradually becoming less practised, and is now confined principally to such mountain breeds as the West Highland, or to the more highly improved breeds, the Short-horn and Hereford. Short-horn breeders sometimes provide a nurse, drying the cow after parturition. With heifers, this practice improves the size, condition, and general symmetry. With cows, the secretion of milk is frequently impaired from the state of obesity in which the animal is kept. Such cows, after parturition, should receive one pound Epsom salts, with one ounce of nitrate of potash, and two drachms of ginger, and the flow of milk encouraged. Cows kept for milk should receive no medicine, an occasional handful of salt excepted. This, given in warm drinks, will tend to induce thirst; to allay which, more water, with the chill taken off, and containing a portion of the water in which barley has been boiled, should be given. The allowance of food should be restricted to two handfuls of boiled barley daily, with hay or green food. No roots, meal, or cake should be allowed for the first three days; after which, if no unfavourable symptoms appear, the quantity of food should be gradually increased, and cake allowed; care being taken that the cow does not partake of cold water for some time after calving.

Calves not suckled should receive warm milk twice, still better, three times in the twenty-four hours. The

* In Dodd's *Food of London*, published by Longmans, will be found much curious information on this interesting subject.

quantity at one time, for the first two weeks, should not exceed three pints. Afterwards, the quantity of milk should be gradually increased. In fattening calves for veal, there is little danger from giving as much milk by the third week as the calf will take. Some feeders give eggs in addition to milk—two or more eggs daily. The shell is broken, and the egg is placed over the root of the tongue. When the allowance of milk is what the calf will drink, chalk should be added occasionally—one quarter to half a pound weight; this assists digestion. The calf intended for slaughtering should be kept dark, confined in little space, and receive no other food than milk. Whiteness of flesh indicates that the feeding has been only milk. The common practice of slaughtering calves a few days, and sometimes only hours old, should be legally suppressed. In France, where upwards of two millions of calves are annually slaughtered, calves cannot be exposed in the metropolitan markets till they are five weeks old. Inspectors of the markets and of the abattoirs render the slaughtering of calves under the legalised age all but impossible. Calves advance in weight about two pounds a day, when they receive seven to ten pounds of milk. Thus a calf weighing at birth 85 to 100 or more pounds, will in five weeks almost double its weight. For the first eight days, the weight rather decreases. Five-eighths to six-eighths of the live weight is considered the dead weight. In this country, veal is not much prized; in France, and some other continental states, from the attention bestowed upon feeding the calves, veal is regarded as a luxury, occupying nearly the same place as lamb in this country.

Calves to be reared, should have abundance of milk for the first four weeks, and that the milk of a cow newly calved. After four weeks, linseed or linseed-cake gruel should be allowed—not mixed with the milk, but given at a different time; the one diet of milk, the other of gruel. Hay or grass may be hung up within reach, and cake finely broken placed in a trough before the calf. As the animal takes to the gruel, cake, and grass, the milk should be gradually withdrawn, care being taken so to maintain condition, that the plumpness of the well-nursed calf is not lost. After the calf eats grass freely, it may, along with others, be turned out to a small paddock, but housed during the night. If a male, and not intended to be reared as a bull, it may be castrated when one month old, a west wind and a mild temperature being chosen for operating. Heifers are now seldom spayed; the operation is difficult, and, except the person is expert, spaying should not be attempted.

Modes of Feeding.

The cow, after recovery from calving, requires an abundance of food, to keep up the secretion of milk. The feeding should be regular, from morning to night, and water must be offered at proper intervals, if the animal has not the full liberty of drinking out of a pond or running stream.

Regarding the nature of the food of cows, although soiling, or artificial feeding in the house, is at all times economical, there can be no doubt that the best milk, butter, and cheese are produced by cows fed on natural pasture. Permanent pastures are to be preferred. Those lands having a damp and saline bottom produce the most suitable food. On enclosed farms, it is the custom of many to keep their cows out both night and day from May till the end of October, so long as a full bite can be obtained; while others bring them into the house twice a day to be milked. In moorland and unenclosed districts, they are put under the charge of a herd through the day, and are brought into the byres during the night. In either case, exposure to wet and cold, or to extreme heats, should be guarded against.

Soiling, or feeding entirely in the house or court-yard, is seldom practised. Partial soiling is occasionally resorted to, by serving out a considerable quantity of rich green food to the dairy-stock in their stalls at night and during the heat of the day. This mode of feeding is more especially followed when the pastures begin to fail; the second crops of clover and first crop of tares, cabbages, and other farm-produce, are all given to the cows in the house at this period. In the best managed dairies in Scotland, when the cows are taken in for the winter, they are never put out to the fields until spring, when the grass has risen so much as to afford a full bite. In the moorland districts, however, they are put out to the fields for some hours every day when the weather will permit. In these districts, the winter food is marsh-meadow hay, occasionally straw, with turnips, boiled chaff, and other refuse from the barn. In the best dairy-districts in England, the cows are fed principally on hay during the winter and spring months. In the vale of Gloucester, &c., the number of acres required for hay equals the number depastured, about 150 stones of hay being produced on the acre. A small portion of roots, turnip, mangold, white carrot, is allowed by most dairy-farmers. Cows in milk have the turnips sparingly supplied. When they are milked, a small piece of nitrate of potash is placed in the milk-pail; the milk as it flows from the udder dissolves the nitrate—this removes almost wholly all traces of the peculiar taste of the turnip.

Where convenient, the cows should be changed from one field to another. Eight days is the longest period they should remain in the same field. Some dairy-farmers prefer to shift the cows daily, grazing in one field during the day, the other during the night, the cows returning to the byres to be milked morning and evening. The study at all seasons when the cows are in milk should be, to provide an abundance of food, succulent, varied, and nutritious. The Scottish adage conveys a great deal of truth—'What gangs in at the *mou* (mouth) maks the guid milk *coo* (cow).'

Milking.

Cows are milked twice or thrice a day, according to circumstances. If twice, morning and night; if thrice, morning, noon, and night. They should not go too long unmilked, for, independently of the uneasiness to the poor animal, it acts injuriously on the secretion of milk.

The act of milking is one that requires skill; for if not carefully and properly done, the quantity of the milk will be diminished. To insure a continuance of the flow of milk, it should, therefore, be thoroughly drawn from the cows until not a drop more can be obtained. Cows should be soothed by mild usage, especially when young; for, to a person whom they dislike, they never give their milk freely. The teats may be washed clean before milking; and when tender, they ought to be fomented with warm water. If there are any sores, lard should be rubbed on the palm of the hand, and afterwards on the teats. The milking and management of the cow should be intrusted only to servants of character. In the majority of the counties of England, it is a common practice to employ men to milk the cows, an operation which seems better fitted for women, who are likely to do the work in a more gentle and cleanly manner. In Scotland, the office is exclusively confined to women; so capriciously do customs seem to vary.

Milk.

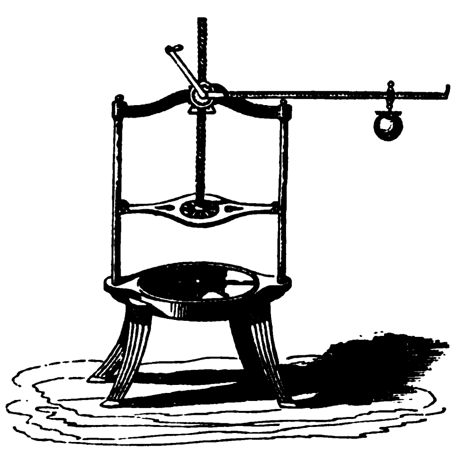
Milk is ascertained to be composed of numerous elements, being in composition similar to blood and flesh, the proportion of water being greater. The milk of the cow seldom contains more than 13 per cent. of solids, the average being about 12 per cent. The character of the food, the breed of cattle, the length of time since the cow has calved, with several other influencing causes, determine in part the relative proportions of the various elements. When taken from the cow, milk should be removed to the dairy or milk-house,

and after being sieved, placed in shallow pans, to throw up the butteraceous matter termed cream, which, like all fatty substances, being lightest, floats on the top.

THE DAIRY.

A well-arranged dairy should consist of separate apartments, in which the various operations can be carried on—the milk-room, the cheese-room, the machine-room, and a boiler-house in which the various utensils can be washed. If completely isolated from other buildings, with the milk and cheese room facing the north, these apartments will be more easily kept cool. A covered verandah before the door, under which the washed utensils may be placed to dry, will be found useful. The milk-room should be cool, airy, dry, and free from vermin of all kinds. To prevent the intrusion of flies, the windows or ventilators ought to be covered with a fine wire-gauze. The floor should be laid with pavement, formed of sandstone, limestone, or slate; smooth glazed tiles are suitable, and where used, they should also be placed around the lower part of the walls. The benches on which the milk-pans are to be placed are made of stone or slate, and about thirty inches broad. The ceiling should be at least eight feet from the floor, and finished in every respect like that of an ordinary dwelling-house. A slate-roof is preferable to one of tile, as it tends to keep the temperature more equable. Cleanliness is most essential in dairy-management.

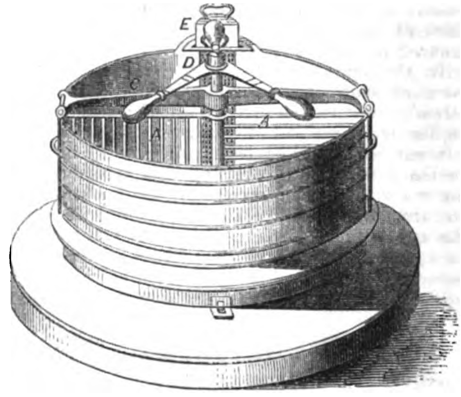
The utensils of a dairy are numerous. The principal are milk-pails, shallow coolers for holding the milk, sieves for straining it through after it is taken from the cow, dishes for skimming the cream, churns for making the butter, scales, weights, &c. For making cheese, there are likewise required vats, tubs, curd-breakers, and presses; and various other articles. Vessels for the milk-room are composed of different materials, wood being generally used—wood lined with tin, cast iron, enamelled earthenware, glass, and zinc. In Holland, the milk-dishes are very commonly made of brass. Zinc, and even lead-glazed earthenware vessels are objected to, on account of the action, or supposed action, of the acid of the milk on these materials producing an active poison. Glass is a good material in which to place the milk; and by using the iron vessels lined with it by a new and durable process (manufactured by the Birmingham Malleable Iron Tube Company), the only objection—its brittleness—is at once obviated.



Messrs Richmond and Chandler's Cheese-press.

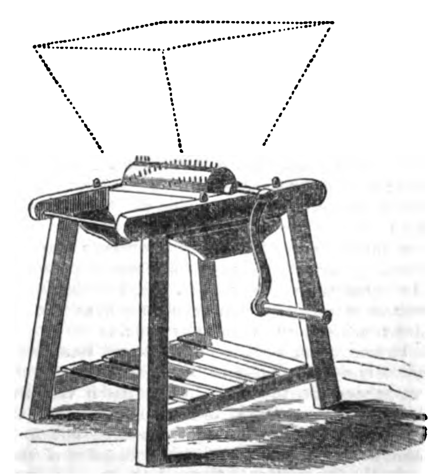
Cheese-presses are of various kinds and weights. Granite is preferred. Presses formerly consisted of a stone weight placed upon the sinker, which was raised and depressed either by a block and tackle or a screw. The above figure represents an improved form of cheese-press, manufactured by Messrs Richmond and Chandler, Salford.

A patent cheese-making apparatus coming into use in well-managed dairies is represented in the following figure. The inventor is Mr Keevil of Lacock, near



Cheese-making Apparatus.

Chippenham. The milk is placed in the apparatus, and curded in the usual manner. When the curd is ready to be broken up, the knives, A, A—one set of which is placed horizontally, the other vertically—are turned gently round by the small levered handle shewn in the drawing. When the curd is cut into sufficiently small pieces, the beam, C, is taken off, the knives removed, and the curd is left to settle. When the whey is ready to be drawn off, the curd is removed with a skimmer from the face of the filter, D; the plug, E, is then drawn out, and a tap, placed at the bottom of the filter, is turned on, and the whey allowed to run off. In the sketch, the plug, E, is shewn partly drawn up; when commencing to use the apparatus, it is of course pushed quite down. When the whey has run off, so as to leave the body of the curd visible, a tub-cloth is placed over it, and on this a *pressing-plate*. A beam provided with a nut, in which a vertical screw works, is then fixed in a position corresponding to C. The pressure of the screw, which is turned by a handle similar to that shewn in the



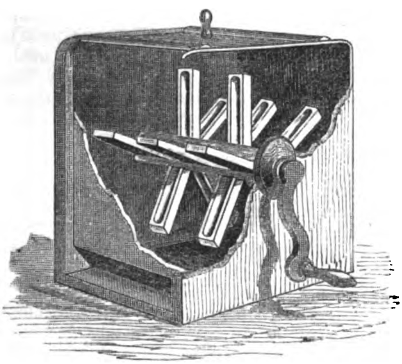
Curd-cutter.

sketch, is transmitted to the pressing-plate through the medium of cross arms or bearers, which are placed over

the pressing-plate before the beam and vertical screw are fixed. The pressure is applied gently at first, till the whey ceases running from the filter-tap. The pressing-plate and arms are then removed, the curd cut and packed in a peculiar manner, and again subjected to pressure. This is repeated till the curd is dry. An apparatus measuring 2 feet 4 inches in diameter, and 1 foot 7 inches deep, holds the curd of forty-two gallons of milk, and is capable of making cheese from ten cows once a day, or from twenty cows twice a day. The price of such an apparatus is £16.

In the figure near the bottom of last column, a form of *curd-cutter* much used in the dairies of Cheshire is represented; it is manufactured by Cornes of Nantwich, Cheshire, price £2.

Great improvements have been recently introduced in the mechanism of *churns*. The *plunge* or *barrel* churn is rarely used except in cases where it can be worked by power. The *box*-churn with vertical dashers is now much used. The annexed figure



Anthony's American Atmospheric Churn.

represents a modification of the box-churn known as Anthony's American Atmospheric Churn. This has a high reputation.

Butter

that is made from milk as obtained from the cow, contains more caseine than butter made from the cream. The greater portion of the butter produced in England is from the cream, which is collected in about thirty-six to forty-eight hours after the milk is placed in coolers, the depth of the milk being regulated to about three to four inches. The cream, as it is gathered and allowed to stand for a time, acquires acidity, the sugar of milk undergoing a chemical change. The butter is produced by churning. The temperature of the milk when put into the churn, the form of the churn, and the speed at which it is moved, all influence the period required to separate the butter from the milk; which milk, after the butter is collected, is termed sour-milk, butter-milk, &c. The time required before the cream of the milk, or the milk drawn from the cow, should be put into the churn, differs materially during warm weather; two days may be sufficient, especially if sweet butter is desired. A longer period than two days, however, is generally observed, as the quantity of the butter is an important element.

The length of time the milk should stand before the cream is skimmed, should be regulated by the weather; during summer, thirty-six hours; but if very hot, with much electricity in the atmosphere, twenty-four hours are sufficient. In winter, forty-eight hours, or even longer, may be necessary to the collection of the whole cream on the surface. To produce superior butter, the cream should be early collected, and only once. Churning should proceed within forty-eight hours after the cream is gathered. The temperature should be regulated to about 51 degrees Fahrenheit in summer, and 55 degrees Fahrenheit in winter; the agent employed, cold or hot water. The temperature at which butter can be produced by agitating the milk, has been ascertained to range from 50 to 80 degrees Fahrenheit. Some colouring matter is usually added to the milk previous to churning. Saffron, anotto, juice of the carrot, are used. All colouring matter should be avoided; but the public opinion as to the colour of rich butter, guides practice. In Holland, the butter produced in winter is white. The colour obtained from the cows depasturing on old rich pastures, is a colour lighter than the greater portion of the butter exposed for sale—salt, powdered, or fresh. Churning at a low temperature retains a portion of the colouring matter, which otherwise would pass into the butter-milk.

The best quality of butter is obtained at a temperature of 51 degrees, according to experiments performed by Mr Poole; and the greatest quantity at a temperature of 56 degrees. During the process of churning, the agitation will increase the heat about 5 degrees.

In some of the dairies in the neighbourhood of Edinburgh, and in all those near Glasgow, as indeed in Scotland and Ireland generally, the butter is made by churning the cream and the milk together. This is done in order to obtain the butter-milk, the demand for which is generally great. When the milk and cream are to be churned together, the milk is kept in the coolers for from twelve to twenty-four hours, and then poured into a milk-tub. It remains here until required for churning, and will, during this time, have partially coagulated. If a certain quantity of milk is put into the milk-tub, and has coagulated, it should be churned, or too much fermentation may be the consequence. The milk is not churned till it has become slightly acid. When once coagulation has taken place, it should be churned as early as convenient. If the milk has not fermented before churning, the butter-milk will keep for a much longer time, and will have a more agreeable taste. When the milk has fermented before being churned, the butter-milk will never be so good, nor will it keep for such a length of time.

The operation of churning, whether it be of cream alone, or cream and milk, is performed in the same manner. The milk requires more time than cream to complete the process, from two to three hours being sometimes necessary, while cream alone may be effectually churned in one-half to one hour. It is necessary that the operation should be slow in warm weather; for if done too hastily, the butter will be soft and white. In winter, the operation of churning should be done as quickly as possible, the action being regular; and the churn should be warmed, to raise the temperature of the milk or cream. The air which is generated in the churn should be allowed to escape, or it will impede the process by the froth which it creates. After the butter is formed, it should remain in the churn to cool for one hour in summer.

After the churning is performed, the butter should be washed with cold spring-water, with a little salt added, the water being changed two or three times, to extract all the milk which may be lodging in the mass. It is said by some, that the butter retains its sweetness much longer when no water is used, the milk being expelled by the pressure of the hands when working the butter. Others affirm that the washing improves the flavour. If butter is intended for salting, it is important to free it of the milk by the use of the hand or butter-platters. After the milk has been extracted, if the butter is to be salted, it should be mixed with the finest salt, in the proportion of ten ounces to the stone of fourteen pounds, more or less, according to the time the butter is to be preserved. The butter and salt should be well mixed together with the hand. In Ireland it is customary to add a little saltpetre. A mixture of one part sugar, one part nitre, and two

parts of the best salt, finely powdered together, has been highly recommended.

In salting, the butter should never be put into the firkins in layers; but the surface should be left every day rough and broken, so as to unite better with that of the succeeding churning. The quality is preserved by covering it from the air with a clean linen cloth dipped in pickle, and finally, by placing it in a cool situation. The air should be excluded by a pickle of salt and water, with a covering of fine linen, over which the top should be pressed down.

The annual import of butter into the United Kingdom for home-consumption, is about fifty-five millions of pounds' weight.

Butter-milk.

This is the liquid which remains after removing the butter. If milk has been employed for churning, the butter-milk is inferior to that from cream. Good butter-milk is exceedingly wholesome and nutritious. In Ireland, it is largely used at meals with potatoes; in Scotland, it is more frequently partaken of with oatmeal porridge. For this purpose, large quantities are brought to Glasgow, Edinburgh, and other towns, from the adjoining rural districts. In England, the butter-milk of farmers is usually employed in feeding pigs. In some districts, skim-milk is also given to pigs. Latterly, butter-milk has been used in conjunction with carbonate of soda in the preparation of a light and wholesome household bread. In the west of Scotland, a kind of cheese is prepared from the butter-milk.

Cheese.

Cheese may be made from cream alone, or from the whole milk; also from skim-milk and from butter-milk; the process consists in separating the serum from the other materials. This is effected by curdling the cream or milk by the infusion of an acid, the refuse being the serum or whey, which is of little value. No acidulous substance is found so suitable for curdling milk as *rennet*, which is formed of the stomach of a calf that has been fed on milk. Some persons preserve the maws or stomach-bags of calves with the curd contained in them; others employ the stomach-bags alone, putting a few handfuls of salt into and around them. They are then rolled up, and hung in a warm place to dry, and are kept for some time before they are used. The stomach is not made use of in Gloucestershire until it is a twelvemonth old; for, if used before this, it is said to swell the cheese, making it full of *eyes* or holes. The usual way of preparing the rennet in England is to add to every six skins or stomachs two gallons of brine, and two lemons, which take away any unpleasant taste, and give the rennet an agreeable flavour. A large quantity is made at a time; and it is never used until it has stood at least two months. In Cheshire the rennet is prepared every morning; a portion of the vel or stomach is cut off, and put into hot water; after it remains some time, the liquid is added to the milk. A portion equal in size to a half-penny, will curd the milk of thirty to forty cows. Rennet so obtained does not impart any disagreeable taste to the cheese. Rennet prepared by the more common method, generally gives an unpleasant taste. Almost every dairy county has its own particular method of steeping and salting the maws and preparing the rennet.

Whey.

Whey, or the thin watery serum of milk, is of a pale-greenish hue, and forms an agreeable beverage. Some dairy-farmers in England are in the habit of extracting a little butter from it. In Scotland, whey is used in making oatmeal porridge; and a saving of nearly one-third of meal is effected when the porridge is made of whey instead of water. By boiling, float-whey, as it is called, is obtained, which, when mixed with a little sweet milk, is thought little inferior to curd. Whey is valuable in feeding swine. Sugar is prepared from whey. The production of crystallised milk-sugar is chiefly confined to Switzerland. It is sold in thick crystalline crusts; colour, yellow and yellow-brown. The production is limited, and does not compete with sugar from the cane or beet-root.

We now propose to give brief descriptions of the process of cheese-making in the most celebrated districts in this country—Cheshire, Gloucestershire, and the west of Scotland.

Cheshire Cheese.—It has been remarked, that although good imitations of the cheese made in the English counties have been produced elsewhere, yet cheese possessing the true Cheshire flavour are exceptional. This is attributed to the abundance of saline particles in the soil. Cheshire is almost entirely a dairy county. In making the cheese, the practice followed is to set the evening's milk apart till the following morning, when the cream is skimmed off, and two or three gallons of the skimmed-milk is put into a vessel, which is immediately placed in hot water, and rendered scalding hot. Half of the milk thus heated is poured upon the night's milk, and the other half mixed with the cream. The morning's milk is added to that of the previous evening, and the rennet and colouring being then put into the tub, the whole is well stirred, and a wooden cover put over the tub.

When the curd is formed, it is cut with the cheese-knife, making the incisions about an inch distant from each other; the whey is removed as it collects on the surface. The curd is then broken by the dairy-woman, until every part of it is made as small as possible, about forty minutes being generally spent in this process, when the curd is left about half an hour to subside, covered over with a cloth. After this, the curd is put in a favourable position in the tub to drain; after which it is cut into pieces, and pressed both with the hand and a weight, so long as the whey continues to flow.

The curd is now broken very small, and salted. As soon as the curd adheres together, a weight is put upon it, and several iron skewers are stuck through it by holes in the sides of the vat. These holes are made in order to allow any whey to escape. The curd is afterwards broken as small as possible. The pressing and skewering are again repeated. When no more whey can be extracted, the curd is turned in the vat, and rinsed in warm whey. The cheese is next put into the press, skewered with strong wires, eighteen or twenty inches long, and sharp at the points. The vat is furnished with holes on the sides to receive the skewers. After being about half an hour in the press, the cheese is turned several times, and each time supplied with a dry cloth. This instrument is continued for forty-eight hours, and then the cheese is put mid-deep into salt, its top covered with salt, where it remains for three days, its position being reversed each day. When taken out of the vat, it is put into a wooden hoop or girth of the same breadth as the thickness of the cheese, and is placed on the salting-bench, where it stands about eight days, being well salted during that time. It is then washed and dried, and rubbed with sweet butter.

These cheeses vary in size, being in some dairies nearly 140 pounds in weight. The quantity of salt made use of during the process is uncertain.

The double Gloucester cheese, which is held in such high repute, is almost wholly made in the vale of Berkeley in Gloucestershire. Its excellence is said to depend much upon the quality of the land, and the great attention that is paid to the management of the dairies. It is usually made in the months of May, June, and July, and the process of manufacturing is as follows:

When the curd—which is seldom prepared from artificially heated milk, but, if possible, from the milk

as it is drawn from the cow, and when it has fallen to about 85 degrees—is considered firm enough for breaking, it is cut gently and slowly into squares of about an inch; standing, to allow the whey to gather, it is again cut. After the whey is removed, the curd is pressed down with the hand into vats, covered with large cheese-cloths of fine canvas, and placed in the press for half an hour. It is then put into a mill, which crumbles it to small pieces, thus saving the labour of squeezing and rubbing with the hands. A cheese-cloth is spread over the vat, and a little hot water thrown over the cloth, which has a tendency to harden the outside of the cheese, and prevent it from cracking. The curd is next turned out of the vat into the cloth, and the inside of the vat being washed in whey, the inverted curd with the cloth is returned to the vat, and is put into the press for two hours, when it is taken out, and dry cloths applied through the course of the day. It is then replaced in the press until salted, which is generally performed about twenty-four hours after it is pressed. In salting, the cheese is rubbed with finely powdered salt; and this is thought to make the cheese smoother and more solid than when the salting process is performed upon the curd. The cheese is after this returned to the vat, and put under the press, in which more than one are placed, the newest one at the bottom, and the oldest on the top. The salting is repeated three times, twenty-four hours being allowed to intervene between each; and the cheese is finally taken from the press to the cheese-room in the course of five days. In the cheese-room, it is turned over every day for a month, when it is cleaned of all scurf, and rubbed over with a woollen cloth, dipped in a paint made of Indian red or Spanish brown and small-beer. As soon as the paint is dry, the cheese is rubbed once a week with a cloth. One pound of anotto is sufficient to colour half a ton of cheese.

The single Gloucester is half skim-milk cheese; 'the double Gloucester or *best making* cheese, is manufactured from the pure or unskimmed milk; although it is not unusual in a large dairy to set aside sufficient milk to afford cream and butter enough for the family, and afterwards to add it to the next day's milking. These are sometimes called *coward* cheeses; they are either thin, weighing about sixteen pounds per cheese, or thick, averaging from thirty to forty pounds. The best single Gloucester is either the *two-meal cheese*, made of equal portions of unskimmed and skimmed milk, or sometimes two portions of skimmed-milk and one part of pure or *coward* milk.'

Stilton cheese is made by putting the night's cream, without any portion of skimmed-milk, into the next morning's milk; but those who wish to make it very fine, add still more cream; and thus its richness depends upon the quantity of cream made use of. Butter is also said sometimes to be used in its manufacture. The rennet is then added without any colouring; and when the curd has formed, it is taken out without being broken, and put whole into a sieve or drainer. In the drainer it is pressed with weights until all the whey is extracted, and when dry, put into a hooped chessel. The outer coat being salted, it is then put into the press, and when sufficiently firm, it is taken out of the chessel, and bound tightly in a cloth. This cloth is changed every day until the cheese is quite dry, when it is removed; and the cheese requires no further care except occasional brushing and turning. The Stilton cheeses, although small—not weighing more than twelve pounds—require two years to bring them to full maturity.

Dunlop cheese, although nowhere so well made as in the parish in Ayrshire from which it derives its name, is now manufactured in the dairy districts of Scotland generally. The cheeses are made of various sizes—from a quarter to half a hundredweight; and the process of making them is as follows. Sometimes the entire milk is used, but generally the cream is removed from the evening's milking. When so many cows are kept upon a farm that a cheese can be made every time they are milked, the milk is passed through a sieve into the vat, and formed into curd by the rennet. But when the cows are not so numerous as to afford milk sufficient to form a cheese at each milking, it is put into the coolers about six or eight inches deep. At the next milking, the cream is skimmed off, and without being heated, the milk is put into the curd-vat along with that just drawn from the cows. The milk is then raised to a temperature about blood-heat, or in summer to 90 degrees, and in spring 95 degrees. If coagulated much warmer, the curd becomes too adhesive; and some of the butteraceous matter is lost in the whey.

After the adding of the rennet, and the removal of the whey, the curd is cut, salted, and prepared for the vat —thirteen ounces of salt to twenty-four pounds being sufficient. A clean cheese-cloth, rinsed in warm water and wrung out, being then placed in the chessel, the curd is put in, and is pressed for about one hour, taken out and turned, and afterwards placed in the press. Some have shortened the process of pressing by placing the cheese, when it comes from the press for the first time, into water heated to about 95 or 100 degrees, where it remains till the water becomes milk-warm. The cheese is then dried well, and again placed under the press.

When ultimately taken from the press, the cheeses are generally exposed for about a week to a considerable degree of drought, turned over every twenty-four hours, and rubbed with a dry cloth. They are then removed to the store-room, which should be in a cool exposure, between damp and dry, without a current of air. The cheese is sometimes coloured with an infusion of anotto or saffron, but the practice is not general.

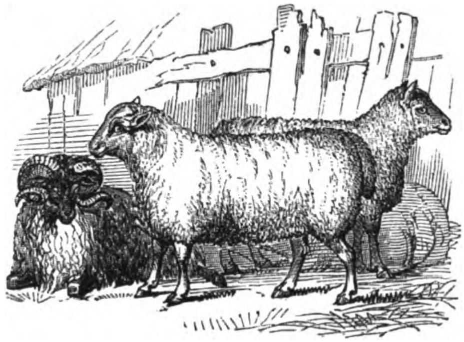
In Ayrshire and in some other counties, imitation cheeses of the most esteemed kinds, Stilton, Cheshire, and Gloucester, are made. A few dairies now produce cheese so closely resembling the best kinds of English in form, colour, and aroma, as to pass with the consuming public as English cheese. A deputation of Ayrshire farmers visited some of the best dairy-farms in England. Since then, more attention is being yearly bestowed on the manufacturing of cheese similar to the English kinds. English dairymaids, where introduced, have found no difficulty in producing superior cheese in the west of Scotland.

Parmesan cheese is manufactured in that part of Italy which lies between Cremona and Lodi, comprising the richest portion of the Milanese territory. The cows are kept in the house nearly all the year round, and fed in summer with cut grass from the rich irrigated meadows of the country. Some of the cheeses are so large as to contain nearly 180 pounds; and the milk of 100 cows is required to produce one of this size. This cheese is made from the milk of the evening, which is skimmed in the morning and at noon, and the milk of the morning, which is also skimmed at noon. The milk is heated to about 120 degrees. The rennet is then added.

Swiss Cheese.—The finest cheese made in Switzerland is that of Gruyere, in the canton of Fribourg. It is rich in quality, and generally flavoured with a powdered dry herb, the *Melilotus officinalis*. The cheeses weigh from forty to sixty pounds each, and are exported in large quantities.

Dutch cheeses are sold under various names in this country—Gouda, &c. Holland exports annually about 30 millions of pounds of cheese, the greater portion coming to England.

The annual import of cheese into the United Kingdom, for home consumption, is about forty-five millions of pounds.



Black-faced—Leicester—South-down.

THE SHEEP—GOAT—ALPACA.

IN the *Ruminant* order of the Mammalia, a distinguished place is given to the sheep, the flesh and wool of which have been recognised as alike of the greatest use to man from the earliest ages. In our own country, within the last half-century, the different breeds have been improved by the growing intelligence, skill, and industry of the farmers; and their management has, under high patronage, been brought to a degree of perfection perhaps nowhere else attained. It may be added that, as the sciences of anatomy, physiology, botany, and chemistry are every year throwing new light on those laws of nature which regulate the structure, health, nutrition, and reproduction of the Animal Kingdom, we may entertain the hope of still further improvement in this department of rural economy.

BREEDS OR VARIETIES OF THE SHEEP.

The numerous varieties of sheep that now exist in different parts of the globe, have all been reduced by Cuvier into four distinct species:—1. *Ovis Ammon*—the Argali. This species is remarkable for its soft reddish hair, a short tail, and a mane under its neck. It inhabits the rocky districts of Barbary and the more elevated parts of Egypt. 2. *Ovis tragelaphus*—the bearded sheep of Africa. 3. *Ovis musmon*—the Musmon of Southern Europe. 4. *Ovis montana*—the Mouflon of America; but this species, which inhabits the Rocky Mountains of North America, is now believed to be identical with the Argali, which frequents the mountains of Central Asia, and the higher plains of Siberia northward to Kamtschatka. This leaves only three distinct species of wild sheep as yet discovered.

It is still a point in dispute from which of these races our domestic sheep have been derived; nor is the question of great practical importance, though its solution is very desirable in a physiological point of view. Whether the wild races may be regarded as of one species, as some naturalists contend, or of different species according to others, the best judges are next to unanimous that the domestic races of this country are of one species; and what are called different breeds, are nothing more than varieties, the result of different culture, food, and climate. The influence of these conditions in diversifying the character and condition of sheep, will be adverted to under their proper heads.

The following may be regarded as the principal breeds reared in this country:

1. *The Shetland sheep*, inhabiting those islands from which they derive their name, and extending to the Faröe Islands and the Hebrides. In general, they have no horns. The finest fabrics are made of their wool, which resembles a fine fur. This wool is mixed with a species of coarse hair, which forms a covering for the animal when the fleece proper falls off. A similar variety is known to inhabit the most northerly parts of Europe, from which it is supposed the fine-wooled sheep of our northern islands and Highlands have been derived. They are hardy in constitution, and well adapted to the soil and scanty pastures on which they are reared, but would ill repay their cultivation in Lowland districts.

2. *The Dun-woolled breed*, the colour of which is not confined to the wool, but extends to the face and legs. They seem at one time to have been cultivated very extensively, and remnants of them still exist in Scotland, Wales, and the Isle of Man.

3. *The Black-faced heath breed*, which, being the most hardy and active of all our sheep, are the proper inhabitants of every country abounding in elevated heathy mountains. They have spiral horns, their legs and faces are black, with a short, firm, and compact body; their wool is coarse, weighing from three to four pounds per fleece; but the improved breed, which is brocked in the face and legs, yields a finer and a whiter wool. They fatten readily on good pastures, and yield the most delicious mutton, weighing from ten to sixteen pounds per quarter. They still exist in considerable numbers in the more elevated mountains of Yorkshire, Cumberland, Westmoreland, Argyleshire, and the central Highlands of Scotland.

4. *The Moorland sheep of Devonshire*—sometimes termed the Exmoor and Dartmoor, from the different districts of Devonshire in which they are reared—have horns, with legs and faces white, wool long, with a hardy constitution, and are said to be well adapted to the wet lands which they occupy. Their wool weighs about four pounds the fleece; but they are rather small, and in some respects ill formed.

5. *The Cheviot breed*, deriving their name from the Cheviot mountains, in which they are said to be indigenous, are longer and heavier than the black-faced. Their wool is fine; a medium fleece weighs about three

pounds; a carcass, when fat, weighs from twelve to eighteen pounds per quarter. Their faces are white; their legs are long, clean, and small boned, and clad with wool to the hough. Their only defect of form is a want of depth in the chest; yet, with this exception, their size, general shape, hardy constitution, and fine wool, are a combination of qualities in which, as a breed for mountain pasturage, they are yet unrivalled in this country.

6. *The Horned varieties of fine-woolled sheep of Norfolk, Wiltshire, and Dorset.*—The members of this breed have short wool, in which they differ from the black-faced sheep and moorland sheep of Devonshire, and from the Cheviot, in having large spiral horns. They are not much lighter than the Cheviots, but they are ill-formed, and thin, flat in the ribs, and slow feeders; a medium fleece weighs about two pounds. It is believed that the South-down will eventually displace them. The Wiltshire sheep are still heavier than those of Norfolk, being the largest of our fine-woolled sheep; they are said to thrive well in the downs of Wiltshire, but are also giving ground to the South-downs. The Dorset sheep have horns, white faces and legs; their three-year-old wethers weigh from sixteen to twenty pounds per quarter; their wool is less fine, but heavier than that of Wiltshire, weighing from three to four pounds the fleece. One of the peculiar advantages of this breed is, the ewes admit the ram at so early a period that they generally have lambs in the months of September and October—a stock which finds a ready market in large towns for winter consumption.

7. *The Ryeland breed*, deriving their name from a southern district in Hertfordshire, which at one time was regarded as incapable of growing anything but rye. The members of this variety are white-faced, and without horns; their general form is tolerable; they fall short of the improved breeds, in being more flat in the ribs, and less level in the back; their wool is fine, weighing from one and a half to two pounds; their mutton is delicate; they arrive soon at maturity, and fatten easily, and weigh from twelve to sixteen pounds per quarter: this breed has been crossed by the Spanish Merino. The offspring of this cross were at one time in high fame in England, under the name of the Anglo-Merino; and though their wool is said to have been of a fine quality, the breed has for long declined in popular favour.

8. *The South-down breed.*—The members of this section have no horns; their legs and faces gray. They have fine wool, which is from two to three inches in length, and weighs from two and a half to three pounds per fleece; they are slightly deficient in depth and breadth of the chest, but their mutton is excellent, and highly flavoured; they are kindly feeders, and when fat, their average weight may be stated at from fifteen to eighteen pounds per quarter. They have, from time immemorial, been reared upon the chalky soils of Sussex, but are now widely extended, and thrive excellently not only on the chalk-downs and light soils of England, but on the sheltered lawns of Scotland. In a note to the author from Lord Pitmilly, near St Andrews, are the following facts: 'I generally keep about a score of South-down ewes for early lambs; they pasture in the lawn with the black-faced wethers kept for family use. The lambs dropped early in winter 1839–40 not being wanted, were sent to Edinburgh; ten of the ewes lambed again in September 1840, and again in March 1841. Some of them had twin lambs; all did well. The September lambs I sold in August 1841, when eleven months old, at 30s. apiece. I ascribe the fact of the ewes thriving so well to the dry ground, and to their being put every night, summer and winter, into a shed, and well bedded; they have no extra food, except at lambing-time, when they get a little oil-cake or sliced turnip.' The above facts are highly deserving the attention of breeders of this variety of sheep, testifying as they do to the greatest degree of fecundity of which we have yet any authentic account.

9. *The Merino breed*, which is supposed to have been originally from Africa. Marcus Columella saw a variety from that country at some of the games exhibited at Rome. He procured some of them for his own farm, crossed them with the breeds of Tarentum, and sent the offspring of this cross to Spain. In Spain, they soon rose to such perfection and celebrity, that they attracted the attention of breeders of stock in other nations, and this breed may now be found in every part of the globe. They were imported into England for the first time in 1788. The Ryeland and other fine-woolled breeds of England were crossed by Merino rams in 1792. The Merino breed of rams were cultivated with great care by George III. The sales of his majesty's stock, which commenced in the year 1804, attracted such general attention in England, that a society was formed for promoting the breed in 1811; but the high expectations which were formed of the result of this cross with native sheep were far from being realised. The quality of the wool of the native sheep was improved, but the increased value of the fleece was an inadequate compensation for defects in the character of the animals themselves, which proved less hardy than the parent stock, were slow feeders, and very defective in form.

The Merinos that have been naturalised in this country retain their natural characters, except that they become larger in the carcass, and the wool longer and heavier, than in Spain; but the Merino, as a feeding animal, is too small and ill-formed, and the mutton deficient both in quantity and quality. These points have given rise to some controversy; but in the forcible language of Professor Low: 'It is vain that some breeders still contend for the superiority of the pure Merino; the general judgment of farmers is against them, and with perfect reason.'

The Merino sheep are cultivated in Spain and Germany with a greater regard to the wool than to the weight and value of the animal; but the farmers in England think it more profitable to raise the weight and value of the mutton; and it is believed, by those well qualified to judge, that the best Merinos, under the more rigorous climate of Britain, would never yield mutton equal in quality to that of Spain. The wool of this breed is finer than that of any other sheep. In Spain, the fleece of the ram weighs eight pounds, and that of the ewe five pounds; but this wool having such a large quantity of yolk, which absorbs every kind of impurity with which it comes in contact, it loses three-fifths of its weight by being properly washed. In Australia, whither Merinos have been imported, the breed has not only improved in size and weight, but the wool produced is quite equal to the finest sorts of Europe—the result of a mild and equable climate, and not ungenerous pasture.

10. *The Devonshire Notts, Romney Marsh, Old Lincolnshire, Teeswater, and Old Leicester sheep.*—The Devonshire Notts consist of two varieties: the one is called the Dun-faced Notts, from the colour of the face; this is a coarse animal, with flat ribs and crooked back, but it yields a fleece weighing ten pounds, and when fat, weighs twenty-two pounds per quarter when only thirty months old. The second variety is called the Bampton Notts; it resembles the former in many respects, but is easier fed, yields less wool, and has the face and legs white.

The Romney Marsh breeds are very large animals, with white faces and legs, and yield a heavy fleece, the quality good of its kind. Their general structure is defective, the chest being narrow, and the extremities coarse. The result of their being crossed by the New Leicester is still a point in dispute—one party alleging, that though the quantity of wool has been lessened, and the size of the animal diminished by the cross, yet the tendency to fatten and their general form have been much improved. On the other hand, some well-informed

breeders contend, that besides the loss of the quantity and quality of the wool, the constitution of the animal is rendered less fitted to the cold and marshy pastures on which it feeds.

The Old Lincolnshire breed are large, coarse, ill-shaped, slow feeders, and yield indifferent mutton, but a fleece of very heavy long wool. The Teeswater breed were originally derived from the preceding, and pastured on the rich lands in the valley of the Tees, from which they derive their name; but Professor Low remarks, that 'it is entirely changed by crossing with the Dishly breed, and that the old unimproved race of the Tees is now scarcely to be found.' They are very large, and attain a greater weight than almost any other breed—the two-year-old wethers weighing from twenty-five to thirty pounds per quarter, and yielding a long and heavy fleece.

The Old Leicester is a variety of the coarse long-woolled breeds. On rich pastures, they feed to a great weight; but being regarded as slow feeders, their general character has either been changed by crossing, or altogether abandoned for more improved varieties.

11. *The New Leicester and Improved Teeswater breeds.*—Mr Bakewell of Dishly, in the county of Leicester, has the honour of forming this most important breed of sheep. He turned his attention to improving the form of feeding animals about the year 1755. The exact method he followed in forming his breed of sheep is not accurately known, as he is said to have observed a prudent reserve on the subject. But we now know that there is but one way of correcting the defective form of an animal—namely, by breeding for a course of years from animals of the most perfect form, till the defects are removed, and the properties sought for obtained. The great properties of the New Leicester for the farmer, are their early maturity and disposition to fatten, in which they excel all other breeds. They are less in size than several other breeds, and their wool is deemed inferior to the Cheviot; but they are now reared with great success in almost every part of England and in the colonies of Australia, whither they and the South-downs were early imported.

That class of sheep now known by the name of the Improved Teeswater, is derived from the old breed. Its improvement has been chiefly effected by crossing with the New Leicester. They are not so large as the older race, but are still the largest of our improved breeds; productive in lambs, and yield a good fleece; yet their form renders them less fitted for general cultivation than the New Leicester.

CHOICE OF BREEDS.

If the farmer has rendered himself master of the constitution and character of the different breeds of domestic sheep, already given, and with the general and peculiar character of the climate, soil, and pasturage of the locality on which he is to settle, the selection of the breed that will, upon the whole, yield him the highest profit, will not be a matter of very difficult calculation. But should an error be committed on this head in the first trial, very slight experience would enable a practical farmer to correct it, unless he belong to that class of persons—unfortunately too numerous—to whom the lessons of history and experience convey neither knowledge nor correction.

The breeds best adapted to the soil and climate of the different districts of Great Britain, are arranged by Professor Low in the following manner: 1*st*, The sheep of the mountains, lower moors, and downs; and 2*d*, The sheep of the plains. The sheep of the first class have sometimes horns, and sometimes want them. The finest of them have no horns—namely, the Cheviot and South-down. One of them, the black-faced heath breed, has coarse wool; another of them, the Moorland sheep of Devonshire, has long but not coarse wool; and all the others have short and fine wool.

Of the moorland and down breeds, as they may be called, the hardiest is the black-faced heath breed; and this property points it out as the most suitable for a high and rugged country, where artificial food cannot be procured. The breed next to this in hardy properties, but surpassing it in the weight of the individuals, is the Cheviot. Where the pasture contains a sufficiency of grasses, this breed deserves the preference over any other known to us for a mountainous country. The next breed deserving of cultivation is the South-down. This breed is suited to the chalky and sandy downs of the south of England. It is in this respect a very valuable breed, but it is unsuited to the more rough and elevated pastures to which the black-faced and Cheviot are naturally adapted.

The moorland and down breeds appear to be the most deserving of cultivation in this country. Of the larger breeds of the plains, the new Leicester is the best adapted to general cultivation, and wherever an improved system of tillage is established, this admirable breed may be introduced. The Leicester, the Cheviot, and the black-faced, have for long been regarded as the breeds best adapted for the different districts of Scotland. That these three breeds have nearly stood in the same numerical ratio to one another for some years, is a good proof that each has been placed in that locality best fitted by nature for promoting its health and productiveness. The Leicester is admirably adapted to the rich alluvial soils of our cultivated plains; the Cheviot breed is peculiarly fitted for the grassy mountains chiefly formed of the transition series of rocks; then our most elevated mountain-ranges are formed mainly of primitive rocks, and covered with coarse herbage and heath, on which none but the black-faced, the most active and hardy of our breeds, could survive.

The above arrangements have generally been acquiesced in as the best possible by the farmers of Scotland. But the claims of South-downs for the middle range of the Highland pastures in Scotland have been urged in the following terms, by an agriculturist of long experience and high standing in his profession—namely, Mr Watson of Keillor: 'Having, during the last twenty-five years, been in the management or possession of a considerable breeding-flock of South-down ewes, varying at different times from 500 to 1000 in number, and during that period having had good opportunities of drawing close comparisons betwixt that and the other breeds of mountain sheep—namely, the Cheviot and black-faced—I have come to the conclusion—and am acting upon it in my own practice—that from a pasture ranging from 500 to 1200 feet above the level of the sea, having a moderate portion of green-sward, the rest whin and heather, there can be no more profitable stock of sheep kept than a flock of South-downs of the best sort. My chief reasons for having preferred this breed are—that the South-down sheep, although naturally spirited and active, are easily controlled by a good shepherd; can go over more ground for their food than any other kind of sheep, without stopping their growth; and when tried by severe storms in winter, will brave it better than even the black-faced Highland sheep; and although reduced very low in spring, sooner pick up condition than the other short-woolled sheep. As a proof of the South-downs' tendency to fatten, when put to good keep, I may mention a fact, that while I have seldom been able to produce a fat Cheviot ewe the same season that she has reared a lamb, I never fail to make good fat of the cast South-downs off grass. Their wool is so closely matted on their backs, and about the head and neck, as to be almost impervious to rain or snow; hence so soon as the storm ceases, they appear dry and comfortable, their coat not the least disordered, and altogether free from that *drouked*—Anglicè, drenched—appearance which longer-woolled sheep exhibit even for days after a winter storm.

'In all my experience, the South-down sheep have kept

remarkably healthy. I have never seen an instance of rot in my flock; while during the last twenty years, I have been forced to clear off a lot of Cheviot and also of black-faced ewes from that incurable disease. This, however, may have been owing more to the unsoundness of the pasture from which I got them, than from any peculiarity of the animals themselves. My average loss in the South-down lot has invariably been much under that of any other sheep I have bred. They are hardy, and easily managed at lambing-time; affectionate mothers, and, on moderate keep, give a great quantity of milk; and if there is any inducement for early lambs, they will go with the ram almost as soon as the lamb is weaned. When crossed with a well-bred Leicester ram, and brought into good keep, they produce perhaps the most profitable lamb that is bred, taking wool and carcass into account. I have for the last ten years put all the ewes I could spare from pure breeding to this sort of crossing, lambing the ewes on turnips in spring, then turning them, as soon as the season would permit, to the hill-pasture—the Sidlaws—till weaning-time, when the lambs are brought to the in-field pastures, and put to turnips for the winter, on which food they are kept for about 2d. per week each, and kept on the earliest grass in spring; so that in a month or six weeks after they are clipped, they are fit for the butcher, who values this cross almost as high as the pure bred South-down. The wool is of the finest quality for combing, and fetches the highest price of any British-grown wool—generally from 2s. to 2s. 2d. per pound; and the clip in a good season will average about six pounds. At sixteen months old, I have never realised less than 40s. each, wool and mutton. In Smithfield, this cross is much sought after.

'On lands where folding is found necessary, the South-down submits to this treatment better than any other breed of sheep; such, indeed, in all cases where I have put them to the test, is their spirit and hardiness, that nothing short of ill-treatment seems to injure them. Combining these facts, I can have no hesitation in recommending a South-down flock of sheep in preference to every other, on such situations as I have now described—namely, too high to be occupied during the whole season by a flock of Leicesters, and under that level above which only the native black-faced breed can be expected to thrive.

'So far as I know, it is not yet sufficiently ascertained by experience how far a cross betwixt the South-down and Leicester may be carried, so as to keep up the activity of the former with the well-known fattening qualities of the latter. Another train of breeding through the black-faced and South-down sheep, whose habits seem so much akin, seems likely to succeed. By this cross, improvement in quality of wool would be gained, while that of the mutton would not be deteriorated.' On the other side, Professor Low remarks: 'The South-down breed is best suited to the chalky and sandy downs of the South of England. It is in this respect a very valuable breed; but it is unsuited to the more rough and elevated pastures to which the black-faced and Cheviot are adapted.'

IMPROVEMENT OF BREEDS.

The first point of essential importance to be attended to by the sheep-farmer is the selection of a breed whose size and constitutional qualities best accord with the climate and the pastures on which they are to feed. An error of any magnitude in these respects would be attended with fatal effects both on the health and productiveness of the flock, and thus ruin the finances of the farmer.

It is true that sheep can exist in almost every country, and may be said to reach nearly from the equator to the poles. They are found approaching the eternal snows and icy barriers of the arctic regions; they are found at great elevations in the Cordilleras of South America, and in the still more elevated Himalaya Mountains of Asia. Yet though sheep can be reared within an immense range of latitude and temperature, it is equally true that the climate and soil fix the limits within which our domestic breeds can be cultivated with advantage. Climatic influences wear down the rocks, and thus form the soil; hence the natural pastures of all countries.

The climate, and the condition of existence which it induces, affect, with irresistible force, the structure, health, and reproductiveness of men and animals from the equator to the poles. The laws of nature cannot be transgressed with impunity. But this condition being accurately adjusted, the next objects which the sheep-farmer ought to keep steadily in view are the quantity and quality of the mutton and the wool. Nature has perhaps forbidden that the same sheep should, in any circumstances, yield the greatest weight of the best mutton, and a fleece of the greatest value. The farmer will be able easily to determine, from the country, climate, and various other considerations, to which of these he should direct his chief attention. In England, for example, the farmer finds it more profitable to promote the weight and quality of the mutton than the wool; while the farmer in Spain, Germany, and Australia, finds it his interest to attend more to the wool than the mutton.

The properties most desirable in the sheep are—1. Size; 2. Form; 3. Early maturity; 4. Constitutional hardiness; 5. Productiveness; 6. Disposition to fatten; and 7. Lightness of offal.

1. The *size* of the sheep must be regulated by the climate, the pasture, and the steepness or levelness of the lands on which it is to feed. One rule never to be violated is, that the size of the sheep should bear some reference to the nature of the pasture; and very heavy sheep are unsuited to very elevated and precipitous mountain-ranges. On this subject, a practical question of very considerable importance is still undetermined, and that is, what is the ratio of food consumed by a large animal and one of moderate size. The result of an experiment is given by Dr Parry, where it is stated, that by breeding small sheep instead of large ones, the numbers were increased from 660 to 890 ewes and lambs, and the profit from £450 to above £724. But this experiment, and all others that have been tried, have never, in our opinion, contained all the elements necessary to determine the question with anything like philosophical accuracy.

2. The *form* of the sheep should consist of that happy combination of anatomical structure on which the health and productiveness of the animal depend; and the points of practical men must be tested by this internal anatomical structure. That eminent surgeon, Mr Cline, in his Communications to the Board of Agriculture, states: 'That the lungs of an animal are the first objects to be attended to, for on their size and soundness the health and strength of an animal principally depend; that the external indications of the size of the lungs are the form and size of the chest, and its breadth in particular; that the head should be small, as by this the birth is facilitated, and affords other advantages in feeding, and as it generally indicates that the animal is of a good breed; that the length of the neck should be in proportion to the size of the animal, that it may collect its food with ease; and that the muscles and tendons should be large, by which the animal is enabled to travel with greater facility; and the bones should be small and clean.'

We may here add a description of the best proportions of a Cheviot ram, by the late Mr Culley of Northumberland: 'His head should be fine and small; his nostrils wide and expanded; his eyes prominent, and rather bold and daring; ears thin; his collar full from the breast and shoulders, but tapering gradually all the way to where the neck and head join, which should be very fine and graceful, being perfectly free from any coarse

leather hanging down; the shoulders broad and full, which must at the same time join so easy to the collar forward, and chine backward, as to leave not the least hollow in either place; the mutton upon his arm or fore-thigh must come quite to the knee; his legs upright, with a clean fine bone, being equally clear from superfluous skin and coarse hairy wool, from the knee and hough downwards; the breast broad and well forward, which will keep his forelegs at a proper wideness; his girth or chest full and deep, and instead of a hollow behind the shoulders, that part, by some called the fore-flank, should be quite full; the back and loins broad, flat, and straight, from which the ribs must rise with a fine circular arch; his belly straight, the quarters long and full, with the mutton quite down to the hough, which should neither stand in nor out; his twist or junction of the inside of the thighs deep, wide, and full, which, with the broad breast, will keep his four legs open and upright; the whole body covered with a thin pelt, and that with fine bright soft wool. The nearer any breed of sheep comes up to the above description, the nearer they approach towards excellence of form; and there is little doubt but if the same attention and pains were taken to improve any particular breed that has been taken with a certain variety of the Lincolnshire, the same advantages would be obtained.'

3. *Early maturity* is a property of great importance to the farmer who breeds and feeds all his own sheep for the shambles; they not only make a quicker return for their food, but yield a higher profit to the breeder than slow-feeding animals. This valuable property of early maturity can be induced by breeding, food, and treatment. The new Leicester variety possesses this property in a higher degree than any other of our domestic breeds, and they also yield a greater quantity of mutton on the same quantity of food.

4. *Constitutional hardiness*, in a rigorous climate, and in bleak and elevated mountains, in which artificial food cannot be obtained, is an indispensable quality. But a farmer will seldom make a wrong selection in circumstances so obvious.

5. *Productiveness* is a property which characterises some varieties of sheep and other animals; it may be extended by careful selection in breeding, and from food and treatment. Pets have almost invariably twin lambs. The draft ewes from the mountains of Scotland have generally twins when taken to a milder climate, and kept on superior food.

6. *Disposition to fatten* is a property of very great importance to feeders, as his sheep can be made fit for the market both in a shorter period and with a less quantity of food. None of our domestic breeds possess this quality in greater perfection than the New Leicester; this quality also may be ascertained by examining the depth and breadth of the chest, according to Sir John S. Sebright. And the great physiologist, John Hunter, found that easy corpulence was concomitant with small bones; it is also accompanied with a pliable, soft, and mellow skin.

7. *Lightness of offal.*—It is obvious that to whatever extent the weight of the offal, or uneatable portion of the carcass, can be diminished, the value of the animal is increased. The perfection of an animal is, when the dead-weight of all the eatable parts approaches the nearest to the weight of the animal when alive.

Principles of Breeding.

The fundamental and essential principles of improving any of our domestic animals by breeding, consist in a skilful selection of those males and females the union of whose qualities will remove the defects and induce the properties desired. The sheep-farmer can neither raise nor keep his flock in the highest perfection of which the climate and pasture admit, without a rigid adherence to this primary principle. It was upon this principle that Bakewell formed his celebrated breed of sheep, and it is the only principle upon which any breed can be raised to the highest perfection of which it admits. *Breeding in and in*, as it is called, has given rise to a long controversy, which our increasing knowledge of the physiology of the animal economy, and a wider induction of facts, carefully observed and accurately recorded, will speedily bring to a final close. The facts now collected from a wide surface, and attested by men skilled in the sciences of physiology and anatomy, as well as by practical breeders of livestock, establish the important fact, that breeding by too near affinities, the offspring degenerates. It is a law of nature, and applies to men and animals, and even plants. The accurate experiments of Mr Knight establish the fact, that in the vegetable as well as in the animal kingdom, the offspring of male and female plants, when not related, possess always more strength and vigour than those of near affinities. Sir John S. Sebright tried many experiments by breeding in and in with dogs, fowls, and pigeons, and found that the offspring uniformly degenerated. Sir John Sinclair relates an experiment with pigs, which he carried so far that the females almost ceased to breed; and if they did breed, the offspring was so small and delicate, that they died as soon as they were born. To breed, therefore, from the same race, but of different families, is now established as the only system that will secure the highest results in the different breeds.

Crossing is a means of improving a breed that requires many concurring circumstances to insure success. The climate and the food must accord with the size and constitution of the animal to be produced. To increase the size of sheep, without augmenting or improving their food, would be a ruinous enterprise, and in the face of all principle. The attempt to increase size by crossing with heavier rams from another country, requires also great care that the food and climate be adapted to the condition and character of the expected race; for it is in proportion as size is gained by crossing, that delicacy of constitution and liability to disease are increased. The constitutional qualities of a race of sheep will not accommodate themselves to the soil or climate of a country differing much in pasturage and temperature from that on which it has been long a native, without time, great care, skill, and attention. Were we to cross our mountain Cheviot ewes with Leicester rams, the offspring would labour under two fatal disadvantages—a constitution too delicate for the climate, and a size above the pasture. An attempt was made in Scotland some years ago to raise the quality of the wool of our mountain-sheep by crossing them with Cheviot rams, and the result, so far as then developed, was a complete failure. It is therefore dangerous to directly transplant the pure Cheviot breed to high-lying districts, the system adopted being that of crossing black-faced ewes with a Cheviot ram; by this method, a hardy Cheviot stock is at length obtained.

It is now generally admitted that the male has a higher influence on the character of the offspring than the female. This law is in beautiful accordance with that beneficent design so visible in the arrangements of nature, as it enables man to bring the domestic animals to their most profitable condition in a far shorter period than if the law had been reversed. There is another fact apparently well established, that the male, by one connection, has a higher influence on the second generation than the actual father. This shews that no important change in the character of any breed can be effected, unless the crossing is continued until the fourth or fifth generation.

Age of the Parents; its Effects on the Sex of the Offspring.—Some very interesting experiments were begun some years ago, the result of which, so far as they go, tend to establish, as a general law of nature, that the offspring of a young ram and ewe, of from four to five years old, will in general be feminine, while that of an old ram and young ewe will in general be masculine.

Could this law be practically acted upon, it would be of immense advantage to breeders of stock in every country, but particularly to breeders of stock in such a country as Australia, in which the rapid increase of the number of stock is an object of so great importance. There is an able paper on this curious subject in the first number of the *Quarterly Journal of Agriculture*, containing the results of the experiments made in France, from which the following facts and views are extracted: 'M. Charles Giron de Buzarcingues proposed at a meeting of the Agricultural Society of Severac, on the 3d of July 1826, to divide a flock of sheep into two equal parts, so that a greater number of males or females, at the choice of the proprietor, should be produced from each of them. Two of the members of the society offered their flocks to become subjects of his experiments; and the results have now been communicated, which are in accordance with the author's expectations. The first experiment was conducted in the following manner: He recommended very young rams to be put to the flock of ewes from which the proprietor wished the greater number of females in their offspring, and also, that during the season when the rams were with the ewes, they should have more abundant pasture than the others; while to the flock from which the proprietor wished to obtain male lambs chiefly, he recommended him to put strong and vigorous rams four or five years old. The following tabular view contains the result of these experiments, which are strongly in favour of the views of M. Giron:

FLOCK FOR FEMALE LAMBS.		
Age of the Mothers.	Sex of the Lambs.	
	Males.	Fem.
Two Years old,	14	26
Three Years,	16	29
Four Years, .	5	21
Total, .	35	76
Five Years and older, .	18	8
Total, .	53	84

N.B.—Three twin-births in this flock. Two rams served it, one fifteen months, the other nearly two years old.

FLOCK FOR MALE LAMBS.		
Age of the Mothers.	Sex of the Lambs.	
	Males.	Fem.
Two Years old,	7	3
Three Years,	15	14
Four Years, .	33	14
Total, .	55	31
Five Years and older, .	25	24
Total, .	80	55

N.B.—No twin-births in this flock. Two strong rams, one four, the other five years old, served it.

'The general law, as far as we are able to detect it, seems to be, that when animals are in good condition, plentifully supplied with food, and kept from breeding as fast as they might do, they are most likely to produce females; or, in other words, when a race of animals is in circumstances favourable for its increase, nature produces the greatest number of that sex which, in animals that do not pair, is most efficient for increasing the number of the race. But if they are in a bad climate, or on stinted pasture, or if they have already given birth to a numerous offspring, then nature, setting limits to the increase of the race, produces more males than females. Yet, perhaps, it may be premature to attempt to deduce any law from experiments which have not yet been sufficiently extended. M. Giron is disposed to ascribe much of the effect to the age of the ram, independent of the condition of the ewe.' The author of this treatise has uniformly observed, that in every favourable season, when his stock was in high condition, he had a much larger number of female lambs than of males; and in one of the most favourable seasons that has occurred during his own personal experience, the female lambs exceeded the males to the number of ninety, in a flock of 600 ewes. The ewes had no artificial food at any season of the year; they lived entirely on the natural grasses of our mountain pastures. They got bog and lea hay in snow-storms, but nothing else.

GENERAL MANAGEMENT.

The management of sheep must be varied according to the nature and character of the breed, the soil and climate, character of the pastures, natural or artificial, the position of the farm in reference to markets, and whether all the sheep upon the farm can be prepared for the butcher, or must all be sold lean, as is the case with those farmers whose flocks subsist entirely on the natural grasses of our mountain pastures; and whether early lambs would be profitable or otherwise. These and many other circumstances must regulate the proper time for admitting the rams to the ewes; hence the lambing-season, the proper time for washing, shearing, dipping, smearing, &c. Different names are applied to sheep at different periods of their age. A young sheep remains a *lamb* from birth till the first smearing-time. From this till the first clipping it is called a *hog*. From the first to the second clipping it is termed a *gimmer*. It is now called a *young ewe*, till it bears its first lamb. When male sheep are cut, they are denominated *wedders;* and, according to their age, are called wedder-hogs, &c. At three years old, the wedder is in its prime for mutton.

Lambing.

The period at which sheep begin to breed is in the autumn of the second year after birth, when both rams and ewes are at their maturity. In the British Islands, the company of the ram is permitted at the beginning of October. The ewe goes with young about 152 days, or between twenty-one and twenty-two weeks, and consequently the lambing-season is at the beginning of March. It is of high importance that sheep, during gestation, should be managed with peculiar gentleness and care, the rash use of the dog being attended with the most pernicious consequences. The ewes should be well but not overfed, as the ewes being in too high condition greatly increases the risk in lambing. Though parturition, being a natural process, cannot be regarded as a disease, still, in the sheep, as well as in many of our domestic animals, it is attended with some risk; and in certain states of the atmosphere, and ewes in too high condition, the loss is often very considerable from inflammation.

'As the period of parturition approaches,' observes an intelligent writer in the *Penny Cyclopædia*, 'the attention of the shepherd should increase. There should be no *dogging* then, but the ewes should be driven to some sheltered enclosure, and there left as much as possible undisturbed. Should abortion take place with regard to any of them, although it does not spread through the flock as in cattle, yet the ewe should be immediately removed to another enclosure, and small doses of Epsom salts, with gentian and ginger, administered to her, no great quantity of nutritive food being allowed.

'The ewes should now be moved as near home as convenience will permit, in order that they may be under the immediate observation of the lamber. The operation of *clatting*, or the removal of the hair from under the tail and around the udder, should be effected on every long-woolled ewe, otherwise the lamb may be prevented from sucking by means of the dirt which often accumulates there, and the lamber may not be able at all times to ascertain what ewes have actually lambed. The clatting before the approach of winter is a useless, cruel, and dangerous operation.

'The period of lambing having actually commenced, the shepherd must be on the alert, yet not unnecessarily worrying or disturbing the ewes. The process of nature should be permitted quietly to take its course, unless the sufferings of the mother are unusually great, or the progress of the labour has been arrested during several hours, or eighteen or twenty hours or more have passed since the labour commenced. His own experience, or the tuition of his elders, will teach him the course which he must pursue.

'If any of the newly dropped lambs are weak, or scarcely able to stand, he must give them a little of the milk which at these times he should always carry about him, or he must place them in some sheltered warm place; in the course of a little while, the young one will probably be able to join its dam. The lambing-field often presents at this period a strange spectacle. Some of the younger ewes, in the pain and confusion and fright of their first parturition, abandon their lambs. Many of them, when the udder begins to fill, will search out their offspring with unerring precision; others will search in vain for it in every part of the field with incessant and piteous bleating; others, again, will hang over their dead offspring, from which nothing can separate them; while a few, strangely forgetting that they are mothers, will graze unconcernedly with the rest of the flock.

'The shepherd will often have not a little to do in order to reconcile some of the mothers to their twin offspring. The ewe will occasionally refuse to acknowledge one of the lambs. The shepherd will have to reconcile the little one to its unnatural parent, or to find a better mother for it. If the mothers obstinately refuse to do their duty, they must be folded by themselves until they are better disposed; and, on the other hand, if the little one is weak and perverse, it must be repeatedly forced to swallow a portion of her milk, until it acknowledges the food which nature designed for its sustenance.'

Male lambs are cut nine or ten days after birth. Weaning, or removal from the mother, takes place from three to four months after birth, according to circumstances. In weaning, the ewes and lambs must be separated so far that they will not hear the bleatings of each other. The lambs are at first put on the tenderest herbage that can be selected. Some ewes may have so much milk, that the udders will swell when deprived of the lambs, and this requires to be attended to by the shepherd at this trying season of his labours.

Food—Tending—Shelter.

The best kind of food for sheep is nutritious grassy pasture, growing on a dry and firm soil. The sheep is most assiduous in picking up food, and will range over a great space in quest of the herbage which it is fond of. In the Highlands of Scotland, and in Australia, where the herbage is scanty, the sheep-farm requires to be very large: twelve miles in length and breadth is no unusual size of a Highland sheep-farm. In countries liable to be covered with snow in winter, grass, hay, or some other vegetable material must be preserved for the subsistence of the flocks when their ordinary walks are under a snowy mantle. Natural meadow-hay and turnips are used in Scotland for winter keep when ordinary resources fail; and the employment of these, in the case of heavy drifts, sometimes saves large numbers of sheep. If the flock can be conveniently driven to a cleared hay-field, such is done in preference to carrying food to the animals; there should be one field for the rams, and another for the lambs, or for sheep in a weakly condition. A general rule for sheep intended for the butcher is, that they should never be allowed to turn lean, but be kept in a constant state of improvement; and that kind of food should be selected that will bring the animals to the highest profit in the shortest time and at the least expense. In well-managed store-farms, sheep are now allowed many kinds of food little thought of in former times, as sliced turnips, oil-cake, &c.; and are, besides, provided with troughs of pure water, and a trough of salt, that they may lick when their taste leads them to that indulgence. In all artificial feeding, the food should be free of dirt or any insect spawn.

Heedless farmers are sometimes apt to purchase and keep more sheep than they can conveniently feed on their grounds, which causes a serious evil. To overstock a farm, where artificial food cannot be obtained, is one of the most fatal errors a farmer can commit. It does not merely diminish the quantity, but also fouls and deteriorates the quality of the food. A farm may be overstocked for a few years, but death will by and by not only lessen the numbers, but diminish to a great extent the health and productiveness of those that survive. Avarice and ignorance have tempted not a few farmers to carry on this unequal struggle against the laws of nature and humanity for years, but it has always ended, as it ever must, either in the farmer's ruin, or in a reformation of his plan.

The tendency which most sheep have to ramble, renders it necessary for them to be attended by a shepherd and his dog. The duties of a shepherd are very irksome, and require to be performed by a man of firm resolution, good temper, and discretion. To keep the flock within bounds may be troublesome, but much may be done in the way of preventive; and at all events, the sheep must not be harassed and chased as if they were so many wild beasts. Being naturally of a timid and gentle nature, the sheep ought to be treated with a degree of gentleness, and taught rather to look up to their shepherd as a friendly protector than a tyrant. Lazy shepherds, who do not exercise a judicious foresight in keeping the flock to its ground, try to remedy the evil by hounding or driving the dog after the stragglers, besides giving no small toil to their own limbs in running. We are desirous to lay it down as a rule, well known to all good shepherds, that there should be *only a rare and cautious use of the dog*. Much also depends on the dog being of the proper breed, and well trained to his duty. A good dog gives little tongue; he is seldom heard to bark; his great knack consists in getting speedily and quietly round the further extremity of the flock, and then driving them slowly before him in the direction which his master has pointed out. A wave of the hand in a certain direction, and a word, are usually enough as a sign. Under-bred dogs bark at and fly upon the poor animals, chasing them hither and thither without any rational purpose. All such dogs should be destroyed, as unfit for the important duties which they are intended to perform. A first-rate shepherd's dog is invaluable to the store-farmer, and no reasonable price should be grudged to obtain one.

We now proceed to quote a few passages on the 'Winter or Storm Feeding of Sheep,' from an article which appeared in the *North British Agriculturist* in 1853, from the pen of Mr Boyd of Innerleithen, a gentleman who has carefully studied the habits and economy of the sheep. 'That food and shelter form the true basis of all animal existence, cannot be questioned for a moment, and it is therefore altogether astonishing that so little exertion has hitherto been made to procure the food necessary for the winter and spring feeding of the woolly inhabitants of our mountains. Independent of self-interest, the mere considerations of humanity alone ought to be sufficient to awaken in the store-master every energy to adopt such measures as are best calculated to procure food and shelter for his flocks during a storm. We are well aware that the quantity of bog-hay that can now be collected, in consequence of the surface-draining of the mountain pasture, is a mere fractional part of that collected in the days of our forefathers; but we are not less aware, that even in the best cultivated districts of Scotland, there will always be a piece of land which may be advantageously used for the raising of hay, by irrigation or surface-manuring, as an addition to the cultivated farm. In all our mountainous districts, there is an abundance of sloping and low land, barren, or productive of the worst herbage in its natural state, which admits of irrigation, from those innumerable rivers and mountain-streams by which these districts are traversed

. . . . . We have ourselves, on the first of August, seen sheep eat salted ferns with every apparent relish which had been cut while young and succulent, and we may therefore with much propriety conclude that salted well-got natural hay would be eaten with still greater relish, at any season of the year, in particular by the lambing ewes in a cold ungenial spring. We have long been of opinion, that if salted food—and the more miscellaneous the herbage, the better—were given to the flocks more frequently, that it would not only be highly conducive to their general health, but that it would exempt them from many of the diseases which they are heir to, particularly the rot, which not unfrequently makes such fearful havoc amongst the mountain flocks in many districts of country. Few or none will dispute the value of a few turnips for their flocks during a storm. . . . . The practice of sending the young sheep from the mountainous districts to the valley to be fed on turnips for a few months during winter, has been abandoned by many, as they found, to their sad experience, that the teeth of their sheep had been so much injured by eating the frozen turnips, that they were in a great measure rendered unfit for permanent or hill stock. One of the greatest errors that can be committed in the management of stock during a storm, is to be too long in commencing the feeding of the flocks. Once allow them to deteriorate, and it will be found no easy matter to restore them again to their wonted health and condition. We have long advocated the propriety of cultivating the whin and broom for the winter feeding of sheep, which ought to be sown or planted in large semicircles, so that they might serve the threefold purpose of food, shelter, and shade. They fill up the blank in green feeding, between the decay of herbaceous plants in autumn and their renewal in spring, and they afford a nourishment more wholesome and palatable than can be afforded to sheep during that interval, with the additional recommendation of being in general suitable to the soil of our pastoral districts. The *Ulex strictus*, or upright Irish whin, has the greatest number of shoots, and being of a less prickly nature than the French or Scotch varieties, it is on that account more relished by the sheep, but from its tender nature, it is extremely apt to be cut down by frost, when the Scotch and French remain unscathed. It may be necessary to state that the Irish whin is a mere variety of the common plant, and can only be raised by cuttings, and cannot be propagated from seed. The whin ought never to be cut, but portions of it should annually be burned to keep its shoots tender and succulent. "If you want a bush, burn a bush," is one of the truest Scotch proverbs. The natural sap in the stumps of the cut whin keeps oozing out until they become like a piece of seasoned timber, and consequently long before it can be discovered that there is any life in the plant whatever; but very different is that of the burned bush; the stumps, in consequence of the burning, have become in some measure hermetically sealed, and consequently the natural sap is retained, which has the effect of producing numerous and vigorous shoots in an amazingly short period of time. It has long been a well-ascertained fact, that both the whin and the broom possess medicinal properties for the sheep, and in particular act as an antidote for the rot. It may be stated with some truth that whins and broom occupy no space, as it will be found from the shelter they give to the soil, that the quantity of grass is not only much greater, but some weeks earlier than it would have been had there been no whins and broom whatever. The planting of whins and broom may be considered a permanent improvement of no ordinary kind, and therefore, ought to be executed principally, if not wholly, at the expense of the proprietor of the soil. . . . Every shepherd of experience and observation must have noticed how very superior in condition the lambing ewes and sheep were which had been fed on whins and broom during a storm, to those which had been fed on the best natural or artificial hay. The former, from their healthy brown colour, more resemble turnip-fed sheep than mountain stock. They are also all but exempted from diarrhœa, which the hay-fed sheep are apt to be seized with the moment they partake of the moist pasture, and which not unfrequently reduces them to a condition anything but calculated to secure a successful lambing-time. From the difficulty of procuring hay during the winter-storm of 1852, many were induced to thin their plantations, that they might give the fir-tops to their sheep, and not a few of them found to be true what was many years ago pointed out by Mr Little, that the woolly people thrive better upon half hay and half tops than upon whole hay. Salted pea-straw, too, is considered by many superior to either natural or artificial hay, for the storm-feeding of sheep, as they have found from experience that their flocks are less apt to fall off in condition than when fed on the former. It may not be generally known that when pea-straw is given to turnip-feeding sheep, that it has not only the effect of communicating to the flesh of the animal a beautiful tint, but at the same time gives a flavour to the mutton, which is highly relished by every palate. A few bolls of oats ought to be at the command of the shepherd, to assist, if found necessary, in eking out the hay during the protracted winter,

> "When boundless snows the withered heath deform,
> And the dim sun scarce wanders through the storm."

It is then that the whins and broom, and the well-sheltered *stell* and the well-filled rack, reward the diligence of man, and insure the security of his flocks.'

In those districts which are exposed to storms, it is important to afford shelter to the flocks. Where there are jutting or overhanging rocks or bushes, the sheep will crowd under their lee, and so far protect themselves from harm; but where the country is bare, it will be necessary to erect artificial walls or enclosures of turf and stone, to which they can be led in cases of emergency. On the exposed hillsides of Scotland, it is usual to build circular folds, locally termed *stells*, of sufficient size for a *cut*, or parcel of sheep. The stell is a rude enclosure, formed of a stone and turf wall about four feet in height, and is placed on a piece of ground known to be seldom drifted. Besides these, there should be on every sheep-farm ample and conveniently situated folds for the various sortings of sheep, such as for weaning lambs, shearing, and draughting or drawing out any animals required. Such folds are ordinarily constructed of *flakes*, or movable wooden palings, and occasionally of rope-netting.

Washing—Shearing—Wool.

Previous to shearing, all the sheep should be collected, and washed to rid the fleece of impurities. Mr Boyd makes the following observations on washing and shearing:

'We would strongly recommend that the river-washing of sheep should be abandoned, and that for ever; and that pond-washing should invariably be substituted in its place. When a pond is to be constructed for the washing of sheep—which can be executed at no expense whatever by the shepherds—it ought, if possible, to be placed in a situation so as it can be conveniently filled from a river by a conduit; not from a small streamlet supplied by mountain-springs, as the nature and properties of spring-water are anything but calculated to discharge fatty matters from wool. The pond ought rather to be small in size than otherwise, so that the heat of the animal's body would have the effect of raising the temperature of the water, which would aid and assist the washing in no small degree; and so soon as a few scores of sheep have been hand-washed, so as to produce the alkaline solution of sufficient strength, the pond should be fed from the river by the conduit, in a ratio corresponding with the

quantity carried off by the wool of sheep. It has long been a well-ascertained fact, that when wool has been so perfectly washed on the sheep's back, that it can be put to the machinery without being previously *scoured*, it not only requires less oil in the preparation, but is less apt to gilt during the process of manufacture, scours better, and is ultimately an article of greater purity. It is worthy of remark, that a clip of wool which had been *smeared* with butter and rough turpentine, fetched the highest price at one of the Edinburgh wool-sales, solely on account of the admirable result which had been produced in consequence of being *pond-washed*—a result which *river*-washing could not possibly have produced.

'Those who have a knowledge of chemistry, will readily perceive the nature of the changes which are effected in the process of the *pond*-washing of sheep. The *yolk*—which may with some propriety be considered the food and protection of the fleece—being a true soap, mixes with the water, but is decomposed by the earths, in solution in the water, or raised from the bottom of the pond, which combine with the oily portion, and leave the alkaline free, which again combines with the oil remaining in the wool, and also extracts it. On this account, the longer we wash sheep in the same pond, it forms the stronger alkaline solution, and acts more effectually in cleaning the wool, and freeing it from oil. The alkaline solution will also act on the oil or grease in the smearing material in the same manner, converting it into soap soluble in water, and it will consequently be detached from the wool.

'The result of the Edinburgh and Leith wool-sales, by public auction, holds out every inducement to the flock-masters in Scotland, who have not hitherto been very particular in the washing of their sheep, to be more so in future, as the best washed clips at these sales have invariably commanded a higher remuneration to the producer, than those which had been indifferently washed. The practical manufacturer, in estimating the comparative value of a well and ill washed clip of wool, not only takes into account the quality, but the probable reduction which will take place in reducing the ill washed to the same degree of cleanness as the well washed; and from his daily experience in witnessing the various degrees of reduction which take place in the scouring of the fleeces, he is the best qualified to give an opinion on the subject; as also to give an accurate estimate of the expense of the scouring and drying, besides the carriage of so much filth contained in the ill-washed wool, which cannot, at the most moderate calculation, be less than 1s. 6d. a stone.

'It must therefore appear self-evident that the pains-taking farmer pockets 1s. 6d. a stone more than his slovenly neighbour; who, from a self-imposed tax, loses 1s. 6d. a stone upon his clip, which he might easily have saved, and at no cost whatever, as the washing of sheep perfectly and imperfectly is one and the same expense.

'Sheep, after being washed, ought to be driven to a clean pasture-field, and there to remain three or four days before they are clipped, not only that the fleece may be dry, but that the tubes of the staple of the fleece should again be in some measure filled with the yolk or natural secretion which gives the fleece a rich glistening appearance, and in no small measure prevents its gilting during the process of manufacture, and ultimately assists materially in the scouring of the yarn or cloth, and although last, not least, the wool weighs considerably heavier than when clipped the moment the fleece is dry.

'Before commencing the shearing of sheep, they ought to be carefully examined, to ascertain whether or not they are really ready for being shorn. Few greater errors can be committed in the management of stock, than that of too early clipping. The practice is highly injurious both to fat and lean stock, and not only retards their improvement, but not unfrequently originates organic disease, both acute and chronic. . . . Sheep invariably lose weight more rapidly by being exposed to the cold in this manner, than by taking no small portion of their food from them; and it is a well-ascertained fact, that if once you allow animals to deteriorate in condition, it requires no ordinary care and attention to restore them to their wonted health and condition. Experiments have been frequently tried with feeding-sheep, by shearing a portion of them early in the season, and allowing the others to remain unclipped for some time longer; and the results have invariably been in favour of those that were last shorn. It will be readily admitted by those who have a practical knowledge of the management of stock, that if too early clipping of feeding-sheep is injurious, it will be still more so to lean hill-stock, which, owing to their reduced condition, are less able to bear the shock of so sudden a transition. Turnip-fed sheep, and those that have been kept in an improving condition during the winter and spring months, are ready for shearing at any time that may suit the convenience of the store-master, provided the weather is suitable for the operation; but widely different is the case with hill-stock, which, generally speaking, deteriorate in condition during the winter and spring months, and whose wool invariably ceases growing sooner or later, which is in a great measure regulated by the weather or the scarcity of food; and under no consideration whatever ought they to be clipped until the new growth of wool, which appears as the pasture gets more abundant, and which acts as a protection from both heat and cold. It is no matter however favourable the weather may be, and otherwise suitable for the shearing of the flocks, if they are not ready for it. When relieved of their winter covering, while the new growth is so thin and short, they are not unfrequently as much distressed by heat as by cold, and in many situations experience great difficulty in finding a place to shelter them from the burning rays of the sun. Nor, in all our experience, have we ever found that the early shearing of hill-stock had the effect of inducing a rapid or an immediate growth of new wool, but rather the reverse. Every shepherd of experience and observation must have noticed that sheep that were not clipped until the middle of July, have a much more abundant and healthier-looking fleece by the latter end of August, than those that had been shorn some weeks before then. The injurious results produced in consequence of early clipping are not confined to the sheep themselves; the lambs, too, are often seriously injured by the falling off of the milk from the ewes, which early clipping never fails to produce.

'In the management of wool, too much care cannot be bestowed to exclude all impurities in rolling it up, which ought to be done in as firm a manner as possible, but without stretching the fleece.'

Mr Walter Buchanan has written directions to the wool-growers of Australia respecting the management of wool, many of which are of general application:

'In order to assimilate the Australian wool as much as possible with the German, in preparing it for market, the fleeces should not be broken, but merely divested of the breech and stained locks, and so assorted or arranged, that each package may contain fleeces of the same character as to colour, length of staple, fineness of hair, and general quality.

'If the washing has been performed at the same time and place, and with an equal degree of care, the colour of the wool is likely to be uniform, and it will then only be necessary to attend to the separation of the fleeces as to length, fineness, and general quality: but if a larger grower has flocks of different breeds, and fed on different soils, care should be taken that the fleeces be separated, first as to colour, and then again as to length of staple, fineness, &c.

'The fleeces being assorted, should be spread one upon another, the neck of the second fleece being laid upon the tail of the first, and so on alternately, to the extent

of eight or ten fleeces, according to their size and weight. When so spread, the two sides should be folded towards the middle, then rolled together, beginning at each end, and meeting in the centre, and the roll or bundle so formed held together by a slight packthread. The bagging should be of a close, firm, and tough nature. The material hitherto most generally used has been sail-canvas, which very ill resists bad weather on a long voyage; and when received here, even in favourable condition, is so dry and crisp, that it will tear like paper: a thicker, twilled, more flexible, and tough material, would be preferable. The size and form of the package may be in length about nine feet, and width four feet, sewed up on the two long sides and at one end, the other end being left open, and the sheet so formed being suspended, with the open end upwards, to receive the bundles, made up as before directed, which are to be put in one at a time, one of the flat sides of the roll or bundle being put downwards, and so on in succession, being well trod down, until sufficiently filled for the mouth to be closed. This is the German mode of packing; but it is doubtful whether smaller packages, of the dimensions that have been hitherto sent from the two colonies, may not be more convenient for so long a voyage. The operation of screwing should be discontinued where it has been practised, as the screw-pressure, and remaining compressed during the voyage, occasion the wool to be caked and matted together in a manner that is highly prejudicial to its appearance on arrival. The practice also of winding up each fleece separately, and twisting a portion into a band, is productive, in a minor degree, of the same prejudicial effect; and it is to avoid this that the making German bundles of eight or ten fleeces is suggested.'

Smearing—Dipping.

Smearing is a process of anointing the skins of sheep with certain ingredients, principally for the purpose of rendering the animal less liable to injury from winter cold—the unguent being a slight counter-irritant—and of destroying the vermin which lodge among the roots of the wool. Smearing with a mixture of tar and butter was general in Scotland in former times. The proportions varied in different districts; but in general six pounds of butter to a gallon of tar were deemed sufficient for twenty sheep. The time for laying on this salve was in the end of October and beginning of November, before the rams are admitted to the ewes, which, in the mountain farms of Scotland, is in general about the 22d of November. The smearing with butter and tar has very much declined of late years, and other salves have been substituted, as well as baths in which the sheep are 'dipped.' A very extensively used bath is Beg's, which is composed of black soap, potash, sulphur, and a small quantity of arsenic. The comparative merits of 'dipping' and 'salving,' is still a question among farmers. In the *Agricultural Journal* for October 1853, Mr Boyd has advocated salving, and we subjoin a condensed view of his argument:

'The salving of sheep is an operation which has been annually performed upon our mountain flocks from time immemorial, and has for its object not only the protection of the animal, but also of the fleece; and that of "dipping" has alone for its object the killing of insects. The operation is generally performed in the beginning of October, while others defer until the month of February or March, in the hope, from the more recent dipping, that their lambing ewes, as well as their lambs, will be less annoyed with kaids and other insects during the spring months.

'The salve we would with most confidence recommend is the "Artificial Yolk Salve;" and when we consider the chemical nature of the composition, it is the most appropriate name which can be given to it as a new salve; for it is of a similar nature, and possesses the same properties, as the natural yolk existing in the wool. . . . It is composed as follows: 30 pounds butter; 8 pounds black soap; 2 pounds soda ash; 5 bottles refined spirit of tar. To this 21 Scotch pints of stale urine is added, to saponify the butter, as also to assist in the equal spreading of the mixture. When stale urine cannot be had, water may be used, when ammonia will of course require to be added sufficient to saponify the fatty matter contained in the composition. The above is found sufficient to salve 100 sheep; and when salving butter can be purchased at 5d. or 6d.—the price generally paid for it—the whole composition will cost at the rate of 2½d. a head. The mixture requires to be constantly stirred during the time it is administered to the fleece, and at a temperature a little above blood-heat.

'This composition has already been used to a considerable extent in the Border counties, and has been found admirably adapted for repelling external moisture, preventing cutaneous diseases, and killing instantly all insects with which sheep are infested. It is now a well-ascertained fact, that all fatty matters, whether animal or vegetable, when used in the salving of sheep, ought to be saponified, which has the effect of very materially lessening the conducting power of heat, in consequence of the porous nature of the composition, and thereby adding greatly to the comfort of our mountain flocks during a storm or a protracted winter. From the nature and properties of the composition, it has not only the effect of preventing the "gilting" or discoloration of the fleece, but improves its felting properties in a very eminent degree, at the same time communicating to the wool an indescribable kindliness to the touch, which the "dipped" fleece, or that produced in the absence of an oily or saponaceous substance, cannot possibly possess. As the cause may not be generally known which produces the gilting or discoloration of the fleece, it may not be considered out of place to mention the fact, that oily and fatty matters are composed of proximate principles, which, upon being exposed for a certain time, and to a particular temperature, gradually assume a different condition; and instead of being found mild and harmless, they acquire an acid nature from the absorption of oxygen from the air. The names of the proximate principles of such matters are stearine, oleine, and margarine; and by this absorption of oxygen from the air, corresponding acids are formed which produce the colour technically called gilting, which is so much dreaded by the manufacturers of white goods. The sole object the manufacturers have in mixing the oil with a slight quantity of tar, previous to its being administered to the wool, is to prevent the decomposition, which is effected by the action of the creosote and other anti-putrefactive substances which it contains.' A chief virtue of the salving process is its protective effect against wet and cold. All oily matter, it is well known, repels moisture; and a salved sheep is known to shew a marked hardiness in facing all sorts of weather, as compared with one that has been dipped. 'The salved flocks, too, are less apt to be injured by their unclean neighbours than those that have been dipped.

'It has long been a well-ascertained fact, that those who labour in woollen factories get their clothes gradually saturated with oil, and their bodies in consequence are regularly anointed with the same substance, which has the effect of exempting them from many diseases to which their neighbours, who follow other professions, are liable. These results have recently had the concurring testimony of the highest scientific authorities of our country; and we are decidedly of opinion that those of our woolly people which crop the lofty summits of our mountains, which have been judiciously salved with an oily and saponaceous substance, will be less apt to be visited with those diseases to which sheep are heir to, than those that were *dipped*, which are liable to be drenched with every shower that falls, and chilled by every wind that blows.'

Along with the improved condition of the animal, the clip of wool is both greater and of superior quality. 'It is the opinion of some who have written extensively on the nature and properties of wool, that the felting properties depend entirely on the construction. From repeated experiments, we have found that, however perfect the construction of wool may be, if produced in the absence of an oily or saponaceous substance, it cannot possess in an eminent degree the felting or milling properties of a clothing material; and we may here repeat the expressive language of the clothier, "that cloth is either made or marred at the mill."

'Although it is not customary to salve sheep which are to be fed off on turnips, we are, nevertheless, of opinion that they would be much benefited in consequence. It must be consistent with the knowledge of every shepherd of experience and observation, that notwithstanding that the sheep, during the feeding-season, are not only amply supplied with turnips, but with other food of a miscellaneous and nutritious nature, still, if they have not been salved, but merely dipped, a gradual diminution invariably takes place of the yolk during the winter and cold months of spring; so that about the beginning of March the fleece has become dry and sapless, and less sound in staple than the fleece of the salved sheep, and consequently much deteriorated, not only in weight, but in many of its most valuable properties.'

DISEASES OF SHEEP.

The sheep, in a state of domestication, is subject to a great variety of diseases; but the most formidable, and by far the most destructive, is

The Rot.

It is unfortunate that in the early stages of rot the disease gives no external intimation of having commenced its destined fatal career; for it is generally at the beginning of diseases that human skill is most efficacious in arresting their progress. Sheep in the early stages of the rot, however, instead of shewing symptoms of disease and decay, acquire a great tendency to fatten, which has been turned to advantage by Mr Bakewell and others. But after the disease has undermined the general health, the animal becomes listless, and unwilling to move, leaves its companions, and sinks rapidly in flesh; its eye becomes sunk, dull, and glassy; the wool comes easily from the skin; the breath becomes fetid; the bowels variable, at one time loose, with a black purging, and at another costive; the skin becomes yellow, and sometimes spotted with black; emaciation now becomes more rapid; general fever is induced, and death ensues. There are various methods by which practical men endeavour to ascertain the incipient symptoms of the disease, but the two following are the most general:

The first is, by handling the sheep on the small of the back, and if the flesh feel firm and solid, the animal is judged sound; but if the flesh feel flabby and soft, and give a crackling sound when rubbed against the ribs, the animal is unsound. The other method is by examining the small veins at the corners of the eyes, and if filled with yellow serum instead of blood, the animal is pronounced unsound; but the greatest practical tact and talent will not always insure success in discovering the early stages of this insidious disease.

Appearances on Dissection.—The whole cellular tissue is filled with a yellow serous fluid; the muscles are pale, and appear as having been macerated, being soft and flabby; the kidneys are infiltrated, pale, and flaccid; the mesenteric glands distended with a yellow serous fluid; the lungs filled with tubercles; the heart enlarged and softened; the peritoneum thickened; the bowels are often distended with water, and sometimes grown together. But the liver is the primary seat of the disease; its whole structure is in different states of disease; one part is scirrhous and indurated, and another soft and ulcerated; and the biliary ducts are filled with flukes. This appears to be the origin of the disease which has involved so many organs, and effected such a vast derangement of the whole animal frame.

Causes.—In endeavouring to ascertain the cause of this disease, it seems natural to begin by inquiring whether those parasites which are found in such numbers in the biliary ducts of the liver are the cause or effect of the disease. The parasites named the liver-fluke—the *fasciola* of Linnæus, the *Distoma hepaticum* of Radolphi, the *planaria* of Goese—are not peculiar to the sheep, but have been found in the biliary ducts of the goat, deer, ox, horse, ass, hog, dog, rabbit, guinea-pig, and various other animals, and even in the human being. The parasite is of a brownish-yellow colour, and resembles a small sole divested of its fins; in size it may be seen from that of a pin-head to an inch and a quarter in length, and half an inch in breadth. It is supposed to be a hermaphrodite, as no distinction of sex has yet been made out: in scientific language, it increases, like many of the lowly organised animalcules, by self-division and gemmation. The spawn or eggs of this parasite are found in great numbers in the biliary ducts of the liver; these eggs are also found in every part of the intestinal canal, and very often seen in the dung of a sound sheep, though always numerous in that of a diseased one. This animalcule, and many other of the *entozoa*, have never been found out of the intestines; but this is not positive proof that they cannot or do not exist out of the body. Mr Blacklock, in his very valuable treatise on sheep, after laying flat all his opponents, comes to the following conclusion: 'From all this data, the conclusion must at once be drawn, that as living flukes cannot reach the liver from without, they must of necessity be produced only in particular states of the animal they inhabit: how they originate, we cannot of course determine, and this is not the place to hazard a physiological conjecture; but it will be found that their appearance in the bile is always preceded by tuberculous deposits on the lungs and liver.'

That Frommon found the fluke-worm in the fœtus of the sheep, is a strong fact, but not decisive; for Mr Blacklock must know that although he is anatomically correct when he states that there is no direct vascular communication between the fœtal and maternal side, yet the indirect communication may be sufficient. And besides this, Mr Blacklock's own views on this point are extremely unphilosophical, as when he says, 'that living flukes cannot reach the liver from without, they (the flukes) must of necessity be produced only in particular states of the animal they (the flukes) inhabit.' This is just saying that the flukes inhabit the animal before its particular states produce them. This must mean that the eggs of the fluke exist in the liver of the sheep, ready to be hatched by the peculiar states of the animal; and as these eggs could not, according to Mr Blacklock, reach the liver from without, the only other alternative is, that the liver lays the eggs when in a healthy state, and hatches them when diseased. This won't do: equivocal generation is absurd. But the limits prescribed forbid the author pursuing this interesting inquiry further: he must simply state his belief that the ova of the fluke are not generated by the liver of the sheep, but find their way to that organ by means not yet ascertained; but these ova are not vivified in the liver except under certain states of that viscus. The ease with which Mr Bakewell could induce rot in his sheep, by putting them on ground which he had previously flooded for that purpose, shews that other circumstances must concur to produce the disease. It is not caused by scanty food, as has often been alleged, for sheep may be starved to death without producing rot; the fact that the sheep has an extraordinary tendency to acquire fat in the early stages of the disease, shews that the causes act as a stimulant at first, and originate a slight degree of inflammation in the liver, as

the first step in the progress of this fatal disease. But the numerous and well-attested facts now obtained from various climes and countries, lead to the conclusion that the nature of the soil and pastures, and the character of the seasons, are the chief agents in causing rot. This view is confirmed by the fact, that rot is most prevalent in wet seasons, and is nearly confined to lands subject to be occasionally flooded with water at certain seasons of the year, and to soils naturally moist and marshy. Moist and level lands of retentive soil, from which water is slowly evaporated by the sun, and a temperature favourable to the decomposition of vegetable matter—on such lands, when not thoroughly drained, rot may be said to be indigenous; while on lands that are dry and hanging, the disease is unknown. The nature of the plants which the soil produces is not so important as the plants being kept in a morbid state by that degree of moisture and heat favourable to their decomposition. These views will be amply verified by any one who will take an accurate survey of the midland, eastern, and southern counties of England, in which the disease is most destructive. Besides supporting the views here advocated, the following passage from the pen of M. Hammond, the founder of the veterinary school in Egypt, is highly interesting to every sheep-farmer: 'It appears every year in Egypt after the falling of the Nile, and it follows and keeps pace with the subsidence of the waters; desolation and death accompany it wherever it passes, and it annually destroys at least 160,000 sheep. As soon as the waters of the Nile subside, the pastures which were submerged are speedily covered by a tender rushy grass; the sheep are exceedingly fond of it, and they are permitted to feed on it all day long. In the course of a very little time, they begin to get fat, when, if possible, they are sold; their flesh is then exceedingly delicate, but soon after this the disease begins to appear, and the mortality commences. The disease is more frequent and fatal when the sheep are first turned on the newly recovered pasture, than when the ground becomes dried, and the rushy grass harder. But if the sheep pasture in the midst of mud, or on the borders of the marshes and canals, rot attends every step; the rot does not occur in elevated countries, where the sheep feed on dry aromatic herbage. The Bedouin Arabs sell all the sheep which they can before they quit the Nile, for then they are in high and prime condition, after which they lose not a moment in reassembling their flocks and driving them back to the desert.'

Prevention and Treatment.—If the true causes of rot have been accurately given, every farmer has in his own hands the most efficient means for its prevention; on all lands that can be defended from being flooded with water, and on all lands whose levels admit of thorough drainage, the manner and amount of drainage must be determined by the position of the land, whether level or hanging, and by the character of the soil, and the quantity of the moisture to be removed; and on all these points each farmer must decide for himself, or be guided by the advice of a competent judge. The only indispensable rule is, that the drainage must be thorough, in order to be effectual; and if the drainage is carried to this point, and the sheep be provided with food and shelter during snow-storms, the farmer will have the pleasure to see the rot, that dreadful scourge of his flock, disappear. This important point is established by practical men whose testimony cannot be impeached, that there would be no rotten sheep found, even upon the most spongy lands in the country. The treatment of rot is confined to narrow limits, from the curious fact that sheep, in the early stages of rot, acquire fat with singular rapidity; and the best thing the farmer can do, as soon as he finds his flock tainted, is to sell them to the butcher for what they will bring in the market. From the condition of the sheep, this forced sale may be attended with considerable loss; but it will be a loss inferior to that sustained in the fruitless attempt to effect a general cure.

Tainted flocks have recovered, it has been alleged, by being sent to pasture on salt-marshes; but though the efficiency of such pasture were admitted, it is a remedy which only a few farmers could obtain. To change the flock to a more dry and elevated part of the farm, when this is practicable, has been attended with favourable results. The free use of salt is universally admitted to be the best medicine within the reach of the farmer for checking the progress of this deadly disease. That many cures have been effected by the proper use of salt, is attested by persons of the highest character and intelligence. Sir John Sinclair states that at Mr Mosselman's farm at Chenoi, beyond the Wavre, he found that salt was used for sheep, and that by allowing them to lick it, the rot was completely cured. And as the only explanation of sheep taking on fat rapidly, in the early stage of the disease, is, that the digestive organs are stimulated for a time by inflammation of the liver, perhaps the disease might be checked *in limine* by copious bleeding; but the disease can scarcely ever be detected at that period in which bleeding would be proper, and bleeding late in this, as in almost all diseases, is fatal. But in this disease the sheep-farmer must direct his energies and care to the prevention rather than the cure, though some of the remedies just mentioned may be of service at the beginning: yet, from the insidious nature of the disease, it can undermine the constitution, before it is perceived, to an extent that no known remedies can restore; so that every sheep-farmer must rest his hopes of safety not in curatives, but in the vigorous use of the means of prevention.

Braxy.

Braxy, or sickness, is an inflammatory disease, whose ravages are chiefly confined to hogs, and those in the highest condition are most liable to be attacked. This disease is not nearly so destructive as it was formerly, when hogs were hirsled. This has been accounted for by alleging the inexperience of hogs in selecting their food, and their tendency to feed too much on the succulent parts of their pasture. Braxy, being entirely an inflammatory affection, may be excited by a variety of causes, such as drinking cold water in a heated state; any great or sudden change of temperature; by hail, snow, or rain; feeding on soft rank grasses, which are apt to excite fermentation, and by extrication of gas, distend the stomach, thus originating inflammation, and sometimes producing sudden death by pressure on the diaphragm. One very frequent cause of braxy is that kind of frosty mornings which load the pastures with hoarfrost. The hogs, from feeding chiefly on dry and binding pastures at that season of the year (from November till March), eat the succulent spots of grass laden with hoarfrost very greedily; and thus the temperature of the stomach is so suddenly lowered to icy coldness, that violent inflammation is immediately produced, and death often ensues in a few hours. In the list of the causes of braxy, the improper use of the dog must not be omitted. It is clear that nothing is more calculated to produce inflammation than violent heating a sheep by incessant use of the dog at seasons of the year so liable to sudden and great falls of temperature.

Symptoms.—The animal appears uneasy, often lying down and rising up, standing with its head down and back raised, taking no food, but often drinking water; fever then ensues, when the pulse becomes strong and quick, respiration laborious and rapid, the skin hot, and the fleece clapped; the eyes are languid, watery, and half-closed; by and by it ceases to follow the flock, and soon dies.

Appearances on Dissection.—On opening the body, the appearances vary, according to the parts affected. Sometimes only the reed is affected, and all the rest of

the viscera appear perfectly healthy, and the flesh not at all affected. In other cases, the effects of violent inflammation are visible through the whole of the viscera, and the entire flesh of the animal is in a state of rapid putrefaction.

Treatment.—From the nature of the disease, it is obvious that the first and most effective remedy is prompt and copious bleeding from the jugular veins; this being effected, the constipation of the bowels must be removed. The best purgative for this purpose is Epsom salts, two ounces for a dose, dissolved in warm water, and followed by thin warm gruels: these remedies would generally prove effectual if applied at an early stage of the disease; but in a large flock of mountain-sheep the disease is frequently not observed by the shepherd till too late for any remedy. Removal to young grass or turnips has been attended with beneficial results. The best preventive of the disease in mountain-sheep is skilful and attentive herding, by preventing the young sheep from fastening too much on marshy succulent spots, and by seeing they graze regularly over every part of the pasture, and be allowed perfect repose for rumination, undisturbed by the dog.

Sturdy.

The proximate cause of this formidable disease is hydatids (see ZOOLOGY, p. 131) formed in the brain, or an accumulation of water or serum in the ventricles of the same organ. Many ingenious writers, both in France and in our own country, have favoured the public with a few facts and much speculation to account for the manner in which hydatids reach the brain, and the causes of the accumulation of water in the ventricles; but none of these speculations are in the least degree satisfactory, and many of them can be shewn to be absurd, from the known anatomy and physiology of the brain of the sheep. Many plans have been adopted to extract the hydatids from the brain. Hogg, the Ettrick Shepherd, was successful by the use of the wire. He says: 'When I was a youth, I was engaged for many years in herding a large parcel of lambs, whose bleating brought all the sturdies in the neighbourhood to them, and with whom I was exceedingly plagued; but as I was frequently knitting stockings, I fell upon the following plan: I caught every sturdied sheep that I could lay my hands upon, and probed them up the nostrils to the very brain with one of my wires, and I beheld with no small degree of pleasure, that by this simple operation I cured many sheep to different owners; but I kept all my projects to myself, for I had no authority to try my skill on any of them;' and he adds, 'that several years passed before I failed in this operation in any one instance.' Nothing approaching this success, however, has ever attended the operation in the hands of any of Mr Hogg's disciples; though, when the hydatid is situated in the ventricles, or in the upper portion of the brain, some farmers and shepherds have acquired such tact in the use of the wire as to cure considerable numbers.

The use of the trephine is attended with some difficulty and danger. It lays open at once an immense space in the brain to the action of the atmosphere, and its consequent irritation, and hence the risk of inflammation. When the situation of the hydatid can be ascertained by the softening of a portion of the skull, to destroy the vitality of the hydatid by perforating it with the trocar or other sharp instruments, is perhaps the method attended with the least danger of exciting inflammation, and hence the most likely to succeed. But the extent to which the disease must have injured the brain, before the softening of the bone could reveal the position of the hydatid, is an insuperable evil, diminishing the chances of success in any mode of conducting the operation that can be devised. There is no medicine that can justly be regarded as of any avail. But carefully observed and accurately recorded facts may yet throw some light on the remote causes of this formidable disease, under that higher anatomical and physiological knowledge which has within these few years been brought to bear on the diseases of our domestic animals.

Pining.

This disease, it is said, was unknown in this country before the sheep-walks were thoroughly drained and the moles exterminated. If this statement is correct, the cause of the malady must obviously be too dry and binding pasture; and in accordance with this view, constipation of the bowels is always present in this disease. To open the bowels freely, and change to young grass, are the obvious remedies; and when both can be readily applied, they seldom fail of complete success.

Dysentery.

This disease begins with violent discharges from the bowels of a green slimy mixture, which in progress of time becomes mixed with blood. It has often been confounded with diarrhœa, from which it differs in many particulars. Diarrhœa attacks young sheep, particularly hogs, occasioned by a sudden rush of grass in the spring, or from too sudden a change from a scanty to an over-rich pasture; when such are the causes of diarrhœa, the mere change to a drier pasture will effect a cure. But dysentery attacks old sheep, and generally does not commence till June or July. Many writers allege that this disease is highly contagious, but the best established facts do not sustain the allegation. The disease prevails in fouled pastures, and in seasons characterised by a peculiar state of the atmosphere with regard to heat and moisture, a certain combination of which renders the malady so fatal to our army, especially in tropical climates. In the treatment of this disease, bleeding is a proper remedy in an early stage; but if late, gentle purgatives alone must be used: Epsom salts or castor-oil, with twenty-five to thirty drops of laudanum, are the best purgatives. Mr Stevenson also used an infusion of logwood, and doses of ipecacuanha, in numerous cases with great effect.

Trembling.

Trembling, or Louping Ill, in mountain flocks, is a disease caused by cold east winds, which are prevalent in April and May, and at which season this disease, after a bad winter, is often very destructive. The animal sometimes leaps from the ground and falls down dead; but more generally it is seized with trembling, loses the power of its legs, and lies on its side, grinding its teeth, and moving its limbs with great violence. The appearances on dissection are very uniform: great congestion of blood in the liver and lungs, and particularly the heart, which is invariably gorged with dark blood; and the brain is also sometimes congested; the whole flesh of the body is as white as if the animal had been killed by the usual process of bleeding.

These appearances, and various experiments, led the writer of this paper to view the disease as the effect of a lost balance in the circulation: the cold east wind acting on the surface of the animal when she is just beginning to return from the lowest point by the coming grass, drives the blood from the surface, congests the lungs and liver, and overpowers the action of the heart with a rush of dark venous blood. The numbness of the limbs, caused by the heart being unable to send the circulation to the extremities, has led some writers to regard the disease as a kind of palsy.

Treatment.—Copious bleeding in the first stage of the attack will often restore the balance of the circulation; but if the animal has been affected some time, it is often difficult to obtain a sufficient quantity of blood, which has been thrown from the surface upon the heart and other internal organs. In this state, the animal must be put into a tub of hot water at 98°, which will cause the blood to flow, and thus restore the action of the heart, and tend to restore the balance of the circulation. After a sufficient quantity of blood has been

drawn, doses of Epsom salts, dissolved in warm water, and followed with thin warm gruels, must be given till the bowels are freely opened. The prompt application of these remedies on the first attack of the disease would in general be successful; but, like many other diseases of sheep, it is not observed till the action of the heart has become too feeble for any remedies to restore the lost balance of the circulation. A sudden surprise has been found to produce trembling, so that the shepherds cannot be too cautious while turning sheep. The same views of the nature, causes, and treatment of this destructive disease are supported by numerous facts and experiments brought forward by Mr Tod, in his prize essay, published in the *Transactions of the Highland Society of Scotland*.

Foot-rot.

This is a disease most prevalent in luxuriant meadows, and in all soft grassy lands saturated with moisture. The opinions entertained regarding its causes are discordant in the extreme. Some writers contend that it is comparatively a modern disease, and was first mentioned by two French physicians, M. Etienne and M. Leibault, who published some cases of the disease in *La Maison Rustique*, in the year 1529. Lulin says that it was brought from Piedmont to Geneva in the year 1786, and that the foot-rot did not exist among Swiss sheep before that period; and in a report of the management of Flemish sheep in 1763, published by authority, foot-rot is not once mentioned. In our own country, it is mentioned by Sir Anthony Fitzerherbert in the year 1523. But whatever may have been its history and progress in other countries, it was very prevalent in Great Britain in 1749. Ellis, who wrote in that year, says 'that it raged particularly in the counties around the metropolis. The ewes were seized with foot-rot, which was communicated to other sound ewes and to the lambs which they suckled; and most of the meadows are so much infected with this sheep malady, that few of the suckling ewes are ever clear of it in a greater or less degree, and the pain and anguish thereof keeps them poor in flesh, and lessens their milk; so that two or three ewes thus affected give no more milk than one full milch-ewe that is in perfect health.'

It will aid the reader to follow with greater clearness the following discussions regarding the nature and causes of foot-rot, to have first a correct view of the healthy anatomical structure of the foot of the sheep, at least in as far as this very formidable disease is concerned. 'There are some points of importance,' says that eminent veterinary surgeon, Mr Dick, 'to be kept in view, in order to understand properly either the functions of the foot of the sheep, or the nature of the diseases to which it is liable. The foot presents a structure and arrangement of parts well adapted to the natural habits of the animal. It is divided into two digits or toes, which are shod with a hoof composed of different parts, similar in many respects to the hoof of the horse. Each hoof is principally composed of the crust or wall, and the sole. The crust, extending along the outside of the foot round the toe, and turning inwards, is continued about half-way back between each toe on the inside. The sole fills the space on the inferior surface of the hoof between these parts of the crust, and being continued backwards, becomes softer as it proceeds, assuming somewhat the structure of the substance of the frog in the foot of a horse, and performing at the same time analogous functions. The whole hoof, too, is secreted from the vascular tissue underneath. There are, besides, two supplementary digits at the fetlock. Now, this diversity of structure is for particular purposes. The crust, like that in the foot of the horse, being harder and tougher than the sole, keeps up a sharp edge on the outer margin, and is mainly intended to resist the wear and tear to which the foot of the animal is exposed.'

This structure of the foot of the sheep is extremely well adapted to Alpine ranges, which are the native abodes of the sheep in their natural state. 'Dwelling by preference,' in the language of Mr Wilson, 'among the steepest and most inaccessible summits of lofty mountains, among its native fastnesses, it is seen to bound from rock to rock with inconceivable swiftness and agility.'

From these facts, it is easy to perceive how our domestic sheep are subject to foot-rot, when confined to a limited range on soft and rich pastures, and in wet and grassy lands. In these situations, the growth of the crust of the hoof exceeds the wear and tear, and soon overlaps the sole, and in this situation is either rent or broken off, when sand or dirt reaches the vascular parts of the foot, and hence inflammation is produced. The animal then becomes lame, suppuration takes place, and ulcers discharge fetid matter; and if these ulcers go on unchecked, they throw out fungous granulations; and if these be allowed to go on, the hoof falls off. When the disease reaches to this extent, the constitutional disturbance is very great from high inflammatory fever, and the animal rapidly loses flesh, and, if unrelieved, dies of fever and starvation.

Such being the nature and causes of the disease, the author of this paper thinks the views of Mr Dick rest upon a more secure and philosophical foundation than any other writer that has come under his observation; and if these views are admitted, the treatment and means of prevention are very obvious. To pare away all the detached hoof, and dress the diseased part with some caustic, perhaps the muriate of antimony, has the greatest weight of authority. But as prevention is in all cases to be preferred to cure, the shepherd should keep a vigilant eye upon the flock, and pare regularly on lands that require it. By the simple means here recommended, the writer has prevented the disease from injuring his flock of sheep for more than twelve years, though the lands were subject to the disease. But if foot-rot be as virulently infectious as it is affirmed to be by a whole host of writers, many of whom are men of high character and attainments, very different means both of prevention and treatment must be adopted. As the decision of the question, whether foot-rot be infectious or non-infectious, is of great practical importance to every sheep-farmer, the evidence on both sides of the question would require to be stated with perfect candour, in order to arrive at the truth. In so far as evidence has been produced, the argument inclines to the side of those who contend for the non-contagiousness of the disease. Mr Dick very reasonably asks: 'Has any one ever attempted to produce the disease by inoculation? If it is highly infectious, surely it will at once be produced by inoculation. But this is not such an easy matter as one would expect, from a disease which is supposed to infect a whole field, and that, too, even if it be of five hundred acres in extent. Gohier, a French veterinarian, first applied a piece of horn from a diseased foot, covered with the matter, to the sole of a sound foot, without effect; secondly, he rubbed a diseased foot against a sound one, without effect; thirdly, he pared the sound foot, and having applied a piece of diseased hoof, the disease afterwards appeared; but in this case the foot afterwards got well of itself, and there seems to have been a doubt in the mind of Gohier as to whether it was truly foot-rot or not. Other French veterinarians have tried similar experiments, and particularly Vielhan of Tulle, and Favre of Geneva; and although I have not seen an account of their experiments, it is said they succeeded in producing the disease by inoculation. Now, it will be asked, Is not this a sufficient proof of its infectious nature? I answer that it is not. It appears to me that this is a strong proof against it. If it is produced with so much difficulty by the direct application of matter, is it not absurd to suppose that a few sheep with diseased feet should infect a whole field? I have not seen an account of the manner in which

the experiments of the French veterinarians have been performed; I know not what quantity of matter was employed, neither have we any account of counter-experiments, nor whether any were tried to prove if a similar effect would not have been produced by the application of any other morbid matter; for example, whether the matter of grease from the heels of horses, or from thrushes, would not have produced similar effects. I have little doubt of such being the case; that suppuration might be produced by inoculating with that or almost any other matter, if, in the operation, the wound was made sufficiently deep; nor would I doubt that disease would be produced if matter was spread over the foot in sufficient quantity, and applied for a sufficient time.'

In support of these views, Mr Black, farm-overseer to his Grace the Duke of Buccleuch, states that he had thirteen score of black-faced sheep, the greater part of which were affected with foot-rot, and many of them crawling about upon their knees. He turned them into a drier pasture, on which were seven score of Leicester and Cheviot sheep. All of the diseased sheep except four speedily recovered, and not one of the Leicesters or Cheviots was infected. This is a very strong fact, from the pressure of which the contagionists cannot easily escape.

The Scab.

This frequent and very mischievous disease has annoyed the cultivators of sheep in different parts of the world from time immemorial. It is mentioned by Ovid, Livy, and in the *Georgics* it is very graphically described by Virgil. In our own country, it is mentioned by our earliest writers; and in Italy, France, and Germany there is scarcely a writer on sheep who does not describe this prevalent and ruinous disease.

Symptoms.—The sheep becomes restless, scratching itself, tearing off the wool with its teeth, and rubbing violently against any post, stone, or gate. When the skin is carefully examined, there are seen numerous pustules, which, having broken and run together, form large patches of scab. The back and shoulders are generally first affected. The general health of the animal sinks in proportion to the extent of the eruption and the virulence of the disease, and if allowed to proceed unchecked, it brings on general inflammation, and the animal dies in a most miserable condition.

It is now ascertained that this disease in sheep is caused by minute insects of the class *acari*. M. Walz, a German veterinarian, has given a very curious and interesting account of the operations of these acari, which are said to burrow in the skin of the sheep, and reappear again about the sixteenth day with a numerous brood. These young insects commence operations at once, and propagate in the same manner, till the poor sheep sinks under myriads of his destroyers. The work of M. Walz contains drawings of these insects, highly magnified. The subject deserves further investigation, being of great importance to the sheep-farmer.

The treatment of scab is thus rendered very simple—the destruction of the insect which caused it. Infusions of tobacco, hellebore, or arsenic, have all been employed with success. In bad cases, the mercurial ointment has been applied with the happiest effect. A very good recipe is a decoction of tobacco and spirit of turpentine, with a little soft soap and sulphur vivum.

The only caution necessary to be given in the use of any of these remedies is, to take care that they be brought thoroughly in contact with every part of the skin of the affected animal, lest any of the burrowed acari escape. And all folds or sheds in which infected sheep have been confined, and all gates, posts, and other rubbing-places, must undergo thorough purification. Besides the acari, sheep are liable to be attacked by various other insects, such as the flesh-fly, and a species of aphis called the sheep-louse. The maggot only prevails in the moist and warm summer months, but increases in numbers with amazing rapidity, and requires great watchfulness on the part of the shepherd, as they soon destroy a large portion of the skin and flesh of the sheep if unchecked. The aphis also creates great irritation; but both species are easily destroyed by any of the preparations already detailed. The tick (*Acarus redurius*) is also a very formidable insect to sheep. It almost buries itself in the skin, and adheres so firmly by six legs, very muscular and powerful, and so armed with serrated claws, that it can scarcely be disengaged from its hold, but will yield, like most of the parasites which infest the sheep, to the application of a mercurial preparation.

Statistics.—The number of sheep in the United Kingdom is estimated at 20,000,000, producing 100,000,000 pounds of wool. The imports of wool amount to about as much more; but some 24,000,000 pounds of the imports are again exported, along with 13,000,000 pounds of home growth. About half the wool imported into Great Britain comes from Australia, and one-third from the Cape of Good Hope. India and China come next in point of quantity, but the heat of the climate renders the wool harsh and hairy. Most of the fine wool for the manufacture of broadcloth was at one time derived from Saxony and other German states, where the merino breed of sheep is cultivated with great success. But this trade has fallen from 30,000 bales in 1830, to 18,000 in 1856, chiefly owing to the increasing supply of fine merino wool from Australia. The total number of sheep in the Australian colonies was stated in 1854 at 17,000,000; and is every year on the increase. The weight of a fleece of wool is from 1½ to 8½ pounds, and the value varies, according to the quality and state of cleanness, from 6d. to 3s.; that of clean Australian wool may be stated at 2s. 6d.

THE GOAT.

Goats form one of the families of the *Ruminant* order of mammalia. The common domesticated goat is usually about the size of the sheep, though less round in form, and is marked by keen eyes, long hair, and generally bent horns. The males, called familiarly in England *billies*, have a long beard; but the females, or *nannies*, are seldom provided with that appendage. Whether in a state of nature or tamed, the goat is remarkably swift and agile, and will browse fearlessly on the most rugged precipices. We find, from ancient writers, that goats have long formed part of the stock of mountain-herdsmen, and were tended with even greater care in former than in present days. In many respects, indeed, the animal is valuable. Its skin is convertible to several useful purposes, and the flesh of the full-grown goat is good, though scarcely equal in quality to that of the sheep. But it is for the milk chiefly that the goat is prized; the qualities of that secretion being not only very nutritious, but even medicinal. Where cottagers have not the means of keeping a cow, a goat will be found a very useful animal, being easily fed, and contented with grasses which are rejected by the cow and the sheep. To those peasants who live in the neighbourhood of mountainous countries, the trouble and expense of keeping a couple of goats will be nothing, as they will find sufficient nourishment in the most heathy, rough, or barren grounds. Heaths, also, which are unfit for any kind of pasture, will afford this animal an ample supply of food; and it requires no care or attention, easily providing for itself proper and sufficient food. In some countries, goats render considerable service to mankind, the flesh of the old ones being salted as winter provision, and the milk is used in many places for the making of cheese. The flesh of the kid is highly palatable, being equal, if not superior in flavour, to the most delicate lamb.

In Britain, the goat produces generally two young

at a time; sometimes three, rarely four. In warmer climates, it is more prolific, and produces four or five at once, though the breed is found to degenerate. The time of gestation is five months. The male is capable of propagating at one year old, and the female at seven months; but the fruits of a generation so premature are generally weak and defective; their best time is at the age of two years, or eighteen months at earliest. A goat is accounted old at six years, although its life sometimes extends to fifteen.

If goats are properly trained, they will return to their owners twice a day to be milked, and prefer sleeping under a roof when accustomed to it. The milk of the goat is sweet, and not so apt to curdle upon the stomach as that of the cow; it is therefore preferable for those whose digestion is but weak. The peculiarity of this animal's food gives the milk a flavour different from that of either the cow or the sheep; for, as it generally feeds upon shrubby pastures and heathy mountains, there is a savoury mildness in the taste, very pleasing to such as are fond of that aliment. The quantity of milk produced daily by a goat is from three half-pints to a quart, which yields rich and excellent cream. If properly attended to, a goat will yield milk for eleven months in the year. In several parts of Switzerland, Wales, and the Highlands of Scotland, the goat is the chief possession of the inhabitants. On those mountains where no other useful animal could find subsistence, the goat contrives to glean sufficient living, and supplies the hardy natives with what they consider a varied luxury. They lie upon beds made of their skins, which are soft, clean, and wholesome; they live upon their milk, with oat-bread; they convert a part of it into butter, and some into cheese; and the flesh furnishes an excellent food, if killed in the proper season, and salted. They are fattened in the same manner as sheep; but taking every precaution, their flesh is never so good or so sweet in our climate as that of mutton. It is otherwise between the tropics. The sheep there becomes flabby and lean, while the flesh of the goat rather seems to improve, and in some places is cultivated in preference to that of the sheep. The cream of goat's milk coagulates as easily as that of cow's, and yields a larger proportion of curd. The cheese is of an excellent quality, and high flavoured; and although to appearance it looks poor, it has a very delicate relish, and strongly resembles Parmesan cheese. Some farmers have been in the practice of adding a little goat's milk to that of cow's, which materially improves the flavour. In winter, when native food becomes scarce, the goat will feed upon turnip-peelings, potato-peelings, cabbage-leaves, and other refuse of a house. In addition to the other products yielded by the goat, its tallow, we should mention, is also an article of some importance. It is much purer and finer than that of sheep, and brings a high price, being calculated to make candles of a very superior quality.

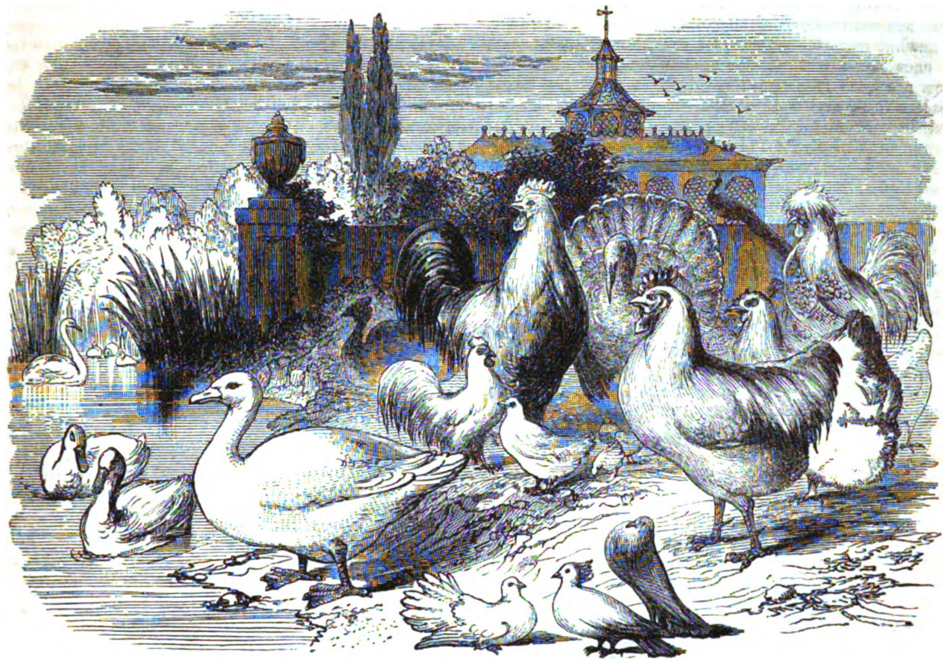
Cobbett advocates the keeping of a goat by cottagers. 'There is one great inconvenience belonging to goats—that is, they bark all young trees that they come near; so that if they get into a garden, they destroy everything. But there are seldom trees on commons except such as are too large to be injured by goats; and I can see no reason against keeping a goat where a cow cannot be kept. Nothing is so hardy; nothing is so little nice as to its food. Goats will pick peelings out of the kennel and eat them. They will eat mouldy bread or biscuit, fusty hay, and almost rotten straw, furze bushes, heath thistles, and indeed what will they not eat, when they will make a hearty meal on *paper*, brown or white, printed on or not printed on, and give milk all the while! They will lie in any dog-hole. They do very well clogged, or stumped out. And then they are very healthy things into the bargain, however closely they may be confined. When sea-voyages are so boisterous as to kill geese, ducks, fowls, and almost pigs, the goats are well and lively; and when no dog of any kind can keep the deck for a minute, a goat will skip about upon it as bold as brass.'

In Britain, no attempts have been made, at least successfully, to introduce foreign breeds of goats, although in France this has been done to a considerable extent. The Cashmere goat, famous for its long silky hair or wool, has been brought to the country mentioned, and there bred with the Tibet goat, a hardier species, but almost equally esteemed for its wool. The manufactures producible from this material, as the Cashmere shawls have long testified, are scarcely to be surpassed for fineness, and yield immense prices. It is probable that, in our warmest districts, a cross of these foreign goats with the common breed might be successfully and advantageously effected.

THE ALPACA.

This animal, an inhabitant of the Andes, below the line of perpetual snow, belongs properly to the family of the *Camelidæ*. Naturalists are not agreed whether it is a distinct species, or merely a variety of the Llama, which was used as a beast of burden by the native Peruvians. The Paco, or Alpaca, has the wool or long hair more developed than the other species or varieties, whichever they may be. The wool is much prized for its silky fineness, length, and lustrous appearance. More than 2,000,000 pounds of Alpaca wool are now annually imported into Britain, where it is used in the manufacture of shawls, coat-linings, cloth for warm climates, umbrellas, &c. Some years ago, attempts were made to naturalise these animals in Britain, but with little success. They are even said to be diminishing in number in their native country, and to threaten, before long, to become extinct.

The Alpaca.



Poultry.

PIGS—RABBITS—POULTRY—CAGE-BIRDS.

PIGS.

TO the humbler classes of society, the pig is only second in importance to the cow. As an object of natural history, it ranks with the *Pachydermata*, or thick-skinned order of the Mammalia—the hog, wild-boar, and probably also the peccary of South America, being varieties of the same family (see ZOOLOGY, p. 183). The most remarkable characteristic of the common pig is its long roundish snout, furnished with a strong cartilage at the extremity, for the purpose of grubbing in the earth for roots and other kinds of food. The feet are cloven, and each possesses four toes, two of which are large, and furnished with stout hoofs, the other two being small, posteriorly situated, and scarcely touching the ground. The body is of a cylindrical form, low set, and thinly covered with bristles, which rise into a strong mane in many of the varieties. The tail is small, short, and in general twisted, and in some varieties is altogether wanting; the ears are either large and pendulous, or short and pointed. The jaws of the pig are powerful; and the teeth with which they are furnished are very formidable, particularly in the wild varieties. Swine do not ruminate (chew the cud); and from this and other peculiarities, they can feed either on vegetable or animal substances—thus forming a kind of link between the herbivorous and carnivorous classes of animals. They are, in fact, omnivorous, and as scarcely any sort of food comes amiss to them, the term 'voracious' is aptly applied to them.

BREEDS—GENERAL MANAGEMENT.

The breeds of pigs most esteemed in Great Britain are the Berkshire, Chinese, and Improved Essex. These are also the breeds best marked by distinctive features; though by crossings, and peculiarities of feeding and position, varieties differing in a slight degree from one another have been raised up in almost every county in England. The Berkshire breed, the parent stock of most of them, is of a reddish-brown tint, with black spots; moderately large ears, inclining forward, but erect; is deep in the body, with short legs and small bone; arrives early at maturity, fattens easily, and with remarkable rapidity. This variety, under good management, grows to an enormous weight. Culley mentions a Berkshire hog, fed by Mr Lawton of Cheshire, which measured, from the point of the snout to the tail, nine feet eight inches; its height at the shoulder was four feet five inches and a half. When living, this huge animal weighed twelve hundredweights two quarters and ten pounds; and when slaughtered, cleaned, and otherwise dressed by the butcher, ten hundredweights three quarters and eleven pounds, or eighty-six stones eleven pounds! The Chinese breed, generally speaking, is of small size. 'The body,' says a good authority, 'is very nearly a perfect cylinder in form; the back slopes from the head, and is hollow; while the belly, on the other hand, is pendulous, and in a fat specimen, almost touches the ground; the ear is small and short, inclines to be semi-erect, and usually lies rather backward; the bone is small, the legs fine and short; the bristles are scarcely deserving of the name, being so soft as rather to resemble hair; the

colour is usually white, sometimes black, and occasionally piebald. The white sort are deemed preferable, from the superior delicacy of their flesh. The face and head are unlike those of any other description of swine, somewhat resembling those of a calf; hence this variety, if once seen, will not be readily forgotten. Chinese hogs are good feeders, arrive early at maturity, fatten on less food, and with similar feeding, become fatter and heavier within a given time than any of our European varieties.' The recently Improved Essex ranks high, for certain purposes, amongst our British breeds of swine. The improvement is said to be due to a cross between the old Essex and the Neapolitan pig; but it is probable also that the Chinese or Berkshire has had something to do in the work of regeneration. The Essex pig is described as up-eared; has a long sharp head; a long and flat carcass, with small bone; colour most frequently black, or black and white; and skin delicate, and almost bare of hair. He is a rapid feeder, but requires a greater proportion of food than the weight he attains to justifies; besides which, he has the character of being restless and discontented. The sows are good breeders, and produce litters of from eight to twelve; but they have the character of being indifferent nurses.

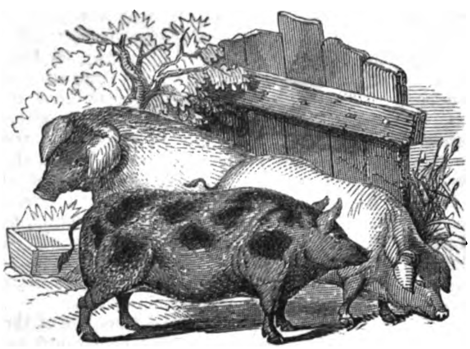


Fig. 1.—Old British—Berkshire—Chinese.

Besides the above varieties—which are at present the favourites at our agricultural exhibitions—the gigantic white and black breed of Cheshire, the white pigs of Suffolk and Hampshire, and the piebald hogs of Sussex and Shropshire, may be mentioned as the best known among the district-breeds of England. They are coarser, generally speaking, than the Berkshire and Chinese. Both of these have been pretty extensively introduced into Scotland, where a less valuable white breed appears to have been earlier located, if not indigenous. There is also a small gray pig, apparently aboriginal, which feeds in herds on the natural pasture on the Highland hills, and furnishes very sweet flesh. By artificial feeding, it can be raised to a considerable bulk. But the breed most commonly esteemed both in England and Scotland is a mixture of the Chinese dark-coloured swine with the Berkshire, or some of the large varieties of British swine. This cross possesses many good qualities, and is peculiarly prolific. Either belonging or allied to the Berkshire variety is the Hampshire *brock*, a small black pig suitable for cottagers, for it is easily fed and fattened, and is therefore highly esteemed. In Ireland, the native pig is described as 'tall, long-legged, bony, heavy-eared, coarse-haired, and by no means possessing half so much the appearance of domestic swine as they do of the wild-boar.' The breed, however, has been greatly improved of late years, and the old unprofitable stock is rapidly disappearing. The improved Irish breeds are now so nearly alike to those of England, that they are not readily distinguishable from each other.

Choice of a Pig.

By whatever name the crop or breed may be called, the following *points* are enumerated by Mr Richardson as those by which the rearer should be guided in his choice of a pig: 'In the first place, sufficient depth of carcass, and such an elongation of body as will insure a sufficient lateral expansion. Let the loin and breast be broad. The breadth of the former denotes good room for the play of the lungs, and a consequent free and healthy circulation, essential to the thriving or fattening of any animal. The bones should be small, and the joints fine. Nothing is more indicative of high breeding than this; and the legs should be no longer than, when fully fat, would just prevent the animal's belly from trailing upon the ground. The leg is the least profitable portion of the hog, and we therefore require no more of it than is absolutely necessary for the support of the rest. See that the feet be firm and sound; that the toes lie well together, and press straightly upon the ground; as also that the claws are even, upright, and healthy. Many say that the form of the head is of little or no consequence, and that a good pig may have an ugly head, it being no affair of anybody but the animal himself which has to carry it; but I regard the head of all animals as one of the very principal points in which pure or impure breeding will be most obviously indicated. A high-bred animal will invariably be found to arrive more speedily at maturity, to take flesh earlier, and with greater facility, and altogether to turn out more profitably than one of questionable or impure stock; and such being the case, I consider that the head of the hog is by no means a point to be overlooked by the intending purchaser. The description of head most likely to promise, or rather to be the concomitant of, high-breeding, is one not carrying heavy bone, not too flat on the forehead, or possessing too elongated a snout—indeed, the snout should, on the other hand, be short, and the forehead rather convex, recurving upwards; the ear, while pendulous, should also be inclining somewhat forward, and at the same time light and thin. Nor would I have the buyer pass over even the *carriage* of a pig. If this be dull, heavy, and dejected, I would be disposed to reject him, on suspicion of ill health, if not of some concealed disorder actually existing, or just about to break forth; and there cannot be a more unfavourable symptom than a hung-down, slouching head, carried as though it were about to be employed as a fifth leg. Of course, if you are purchasing a fat hog for slaughter, or a sow heavy with young, you are scarcely to look for much sprightliness of deportment; but I am alluding more particularly to the purchase of young stores, the more general, because the more profitable, branch of pig management. Nor is colour to be altogether lost sight of. In the case of pigs, I would, as in reference to any other description of live-stock, prefer those colours which are characteristic of our most esteemed breeds. If the hair be scant, I would look for black, as denoting connection with the delicate Neapolitan; but if too bare of hair, I would be disposed to apprehend too intimate alliance with that variety, and a consequent want of hardihood, that, however unimportant, if pork be the object, renders such animals hazardous speculations as stores, from their extreme susceptibility of cold, and consequent liability to disease. If white, and not too *small*, I would like them as exhibiting connection with the Chinese. If light or sandy, or red with black marks, I would recognise our favourite Berkshire; and so on with reference to every possible variety of hue. These observations may appear trivial; but I can assure my readers that they are the most important I have yet made, and that the intending pig buyer will find his account in attending to them.'

Breeding—Littering.

As in the case of other domesticated animals, so with the pig—a perfect, profitable race cannot be maintained without careful and judicious breeding. 'In selecting the parents of your stock,' says the authority above quoted, 'you must diligently bear in mind the precise objects you may have in view—whether the rearing for pork or bacon; and whether you desire to meet the earliest market, and thus realise a certain profit with the least possible outlay of money, or loss of time; or whether you mean to be contented to await a heavier, although somewhat protracted return. If bacon and the late market be your object, you will do well to select the large and heavy varieties, taking care to ascertain that the breed has the character of being at once possessed of those qualities most likely to insure a heavy return—namely, *growth* and *facility* of taking fat. If, on the other hand, your object be to produce pork, you will of course find your account in the smaller varieties; such as arrive with greatest rapidity at maturity, and which are likely to produce the most delicate flesh. In producing *pork*, it is not advisable that it be too fat, without a corresponding proportion of lean; and on this account I would recommend that you rather take a cross-bred sow than a pure Chinese stock, from which the over-fattening results might most naturally be expected.

'In every case, whether your object be pork or bacon, the points to be looked for are—in the Sow, a small, lively head, a broad and deep chest, round ribs, capacious barrel, a haunch falling almost to the hough, deep and broad loin, ample hips, and considerable *length* of body in proportion to its height. One qualification should ever be kept in view, and perhaps should be the first point to which the attention should be directed; namely, the *smallness of bone*. Let the Boar be less in size than the sow, shorter and more compact in form, with a raised and brawny neck, lively eye, small head, firm, hard flesh, and his neck well furnished with bristles; in other respects, look for the same points as I have described in reference to the sow. Breeding within too close degrees of consanguinity, or, as it is technically termed, *breeding in and in*, is calculated to produce degeneracy in size, and also to impair the animal's fertility; it is therefore to be avoided, although some breeders maintain that a first cross does no harm, but, on the contrary, that it produces offspring which are predisposed to arrive earlier at maturity, and take fat with greater facility. This may in some instances be the case: it is so with horned cattle; but as far as swine are concerned, it is not my own experience, and I still adhere to the recommendation I have given. Differences of opinion also exist as to the precise age at which breeding is most advisable. Pigs, if permitted, breed at the early age of six or seven months; but this is a practice not to be recommended. My advice is, to let the female be *at least* one year old, and the male *at least* eighteen months; but if the former have attained her second year, and the latter his third, a vigorous and numerous offspring are more likely to result.'

The sow is very prolific, compared with other large-sized quadrupeds, and for that end is provided with from twelve to sixteen teats. Her period of gestation is sixteen weeks; the number of young varies considerably, being frequently below ten, and occasionally rising to twenty. The young pig is exceedingly delicate; and the brood sow should not be allowed to farrow in winter, but in spring and autumn, when the weather is less severe and food more abundant. Another peril to the litter arises from the semi-carnivorous habits of the mother, which lead her to forget the dues of nature, and devour her own brood. She ought, therefore, to be well watched, and fed abundantly at such periods. The male, for the same reason, must be excluded altogether. Not unfrequently, moreover, the young are crushed to death by the mother, in consequence of their nestling unseen below the straw. To prevent this risk, a small quantity only of straw, dry and short, should be placed below them. The young are weaned when six weeks old; and after weaning, it is essentially necessary to feed them with meal and milk, or meal and water.

Many persons labour under the notion that swine, while breeding, should be kept lean; but nothing can be more erroneous; for, after farrowing, great part of those juices which would be converted into milk, were she in good condition, will naturally go towards nourishing her system. When required for the purpose of fattening, the male young pigs are cut, and the females spayed, which is an analogous process. These operations should always be intrusted to a farrier or other properly qualified person. At weaning-time, it is also customary to 'ring' the young pigs; that is, to insert a ring of iron in the cartilage of the nose, to prevent the animal from grubbing and turning up the floor of the piggery. In pigs intended to be turned to the woods or fields, this process is especially necessary; and where requisite, is preferable to the barbarous and less effectual plan of cutting off the cartilage altogether.

Pig-houses.

The opinion which once almost universally obtained amongst agriculturists and others, that any place was fit enough, and any treatment good enough, for pigs, is fast becoming exploded; contrary to popular belief, pigs are cleanly animals, and if kept in clean sties and supplied with clean litter, will soon shew that they are so. When the food given them, and everything about them, is filthy, it is folly to expect that their habits will be any other than filthy too. Let us, then, beseech all pig-keepers under whose eye this sheet may come, to preserve the sty in the driest and cleanest condition possible, to change the straw frequently, and to curry the skin of the pig at least once a week. By doing so, without a particle of additional food, the animal will thrive and fatten to a very superior degree, while the flesh will be more pure and delicate.

Pigsties, as arranged in a first-class farm, are of three kinds—for breeding, for feeding, and for weaned pigs. For the first, a sty of six square feet will be sufficient, opening into a yard of the same dimensions, in which the feeding-troughs are placed. The feeding pigsty, if four feet square, with a yard of the same dimensions, will accommodate two pigs; the yard and sty for weaned pigs should be some twenty or twenty-five feet square. The yards of all should be in such a position as to have plenty of sun; pigs delight to bask in his beams. As sows are fond of roaming, and easily open doors not well hinged, Mr Stephens recommends grooves to be cut in the front wall of the yard on each side of the doorway, into which a timber-door slides. No sow, however cunning, will be able to force this. The floors of the inner compartments should be well boarded; that of the yard, paved or flagged; the walls should be hollow; and due means should be taken to catch and convey the liquid manure to the tank. An excellent form of feeding-trough is now much used. That part of the trough in the inside of the yard is divided with partitions, reaching some distance into the yard, so that each pig can quietly take his meal without being forced away by a stronger animal, as is often the case in ordinary troughs, where they all feed in common. Another contrivance is also attached, by which the usual inconvenience occasioned to the attendant in filling the ordinary trough, is obviated. Part of the trough being outside the sty, a swing-door or iron plate is suspended on hinges from its upper end; when this is pushed forward towards the yard-side of the trough, and kept in this position by a catch, the pigs cannot obtain entrance; the whole of the trough is therefore exposed to the attendant, so that he can easily place

the food without being annoyed by the pigs. When filled, the swing-door is pulled towards the outside, and there kept by the catch, and the pigs have free access to the trough. The form of feeding-trough on this principle is shewn in the annexed figure. It is built

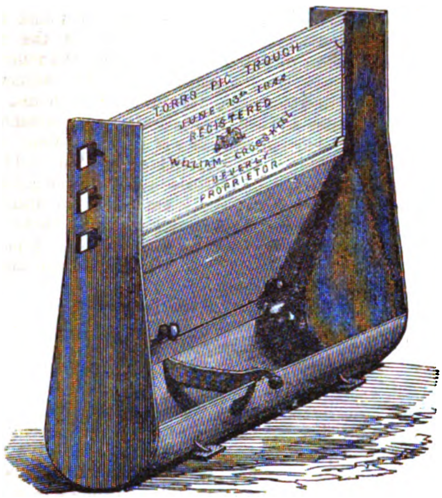


Fig. 2.—Crosskill's Feeding-trough.

in the wall of the sty, and may be used to feed pigs on either side. A good form of feeding-trough for a yard would be a circular one, divided into compartments; these being extended radially for some distance, forming a series of stalls into which one pig only could gain admittance. The cut represents Ransomes

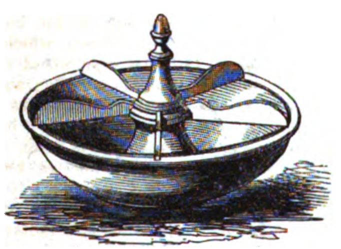


Fig. 3.—Circular Pig-trouga.

and Sims' circular trough for feeding pigs in an open court.

Swine in a domesticated state require to be kept very dry and warm, otherwise they will never thrive. It will be noticed that in cold weather they invariably bury themselves among the straw and litter with which they are supplied as bedding, thus pointing out their natural desire for heat. Keep plenty of straw both in the pig-house and its court, in order to absorb moisture or dung, and let all be raked out regularly and renewed.

Feeding.

In rural situations, where extensive woods exist, and where the grass is otherwise of no value, the feeding and breeding of pigs will be found very profitable to the cottager; for, where they have a wide range, they will require little food save what they find for themselves in grazing under the trees, and in digging for worms and roots of various kinds—for which latter operation their long and strong snouts peculiarly fit them. Artificial feeding is only resorted to in winter, and when the pigs are to be fattened for the market or table. It is more common, however, for the cottager to keep one or two pigs entirely within a sty, to add to the means of subsistence of his own family; and even when kept with this limited view, the pig is a creature of no little consequence. As Cobbett acutely and pithily observes: 'The sight of a flitch or two of bacon on the rack tends more to keep a poor man from poaching and stealing, than whole volumes of penal statutes. They are great softeners of the temper, and promoters of domestic harmony.'

When a young pig is to be purchased for feeding and killing, it is advisable to buy one which will be about sixteen months old at Christmas—that or some time in January being the preferable period of slaughtering the animal. Unless for delicate pork, it should not be killed less than a year old. During the summer, the pig may be fed on any refuse from the kitchen or garden, including turnip and potato parings, table-waste, cabbage-leaves, &c.; but if barley-dust, or grains from a distillery, can be economically procured, either forms a good article of diet. Let it be kept in remembrance that the finer the feeding, the finer will be the pork. The food should, at all events, be of a vegetable kind, or principally so; nothing beyond refuse from the table being advisable in the shape of animal food. Whatever be given, let it be offered in small quantities, and frequently, it being a matter of importance never to allow the pig to become violently hungry. The half-starving system of feeding is poor policy, and is repaid by a lank poor carcass, scarcely worth killing.

Farmers possess great advantages for feeding pigs: the straw-yard of itself affords continual support to them; and many pigs reach the age of one year without having received any food but what they themselves have gathered, yet are in good condition. What with the sweepings of the barn, and the straw, turnips, carrots, and clover, lying about a steading, with the refuse of the kitchen, a farmer, it has been calculated, may sustain swine in the proportion of one to every seven or eight acres of land under crop, without being conscious of the consumption made by them. In few instances are swine reared in such numbers as to have crops specially laid out for them, though some writers assert that they would yield in such a case greater and readier profits than other live-stock habitually reared in the same way. Where rearing on the large scale is attempted, a proper plant of sheds, courts, and feeding-troughs is erected; and besides the miscellaneous refuse of the farm, special crops of coarse potatoes, cabbage, carrots, and Swedish turnips are grown for the piggery.

About the month of September, the process of fattening pigs should commence, whether they be designed for pork or bacon. If for pork, the fattening need not be carried to the same extent. In either case, a nourishing diet must be given, the only precaution being not to commence feeding too rapidly, otherwise surfeit may be produced. The best materials for feeding are barley and peas meal; and if milk, either skimmed or churned, can be given at the same time, it will greatly facilitate the feeding, and improve the quality of the flesh. Many persons feed their pigs on potatoes; but in that case the flesh is not so solid and good, and the fat is somewhat loose and flabby. Soft meat may do very well for pigs when they are growing, but it is not the food which should be given when they are fed for killing. Those who keep pigs for their own use, generally give them a feed or two of corn daily for fourteen days before they are killed, and give them nothing else but churned or skimmed milk to drink; and for a day before killing, the pig should not get any food. Where people's circumstances will not permit any of the modes of feeding for killing which we have above pointed out, boiled potatoes, mixed with a handful or two of oatmeal, may be resorted to as a substitute. It is undeniable, notwithstanding what has been said above, that the Irish

peasantry produce excellent pork by feeding their pigs almost entirely on potatoes. It is not so fat as the pork produced from peas and barley, but it is on that account the better suited to stomachs unaccustomed to very strong food. Swedish turnips, carrots, and broken corn, with a little bean or peas meal, make an excellent fattening dietary, and can be procured at little more than half the expense of the old potato-and-meal system.

In concluding the subject of feeding, we cannot do better than reiterate the following sound injunctions by Mr Richardson: '1. Avoid foul feeding. 2. Do not omit adding salt in moderate quantities to the mess given—you will find your account in attending to this. 3. Feed at regular intervals. 4. Cleanse the troughs previous to feeding. 5. Do not overfeed; give only as much as will be consumed at a meal. 6. Vary your bill of fare. Variety will create, or, at all events, increase appetite, and it is further most conducive to health. Let your variations be guided by the state of the dung-cast: this should be of a medium consistence, and of a grayish-brown colour. If hard, increase the quantity of bran and succulent roots; if too liquid, diminish or dispense with bran, and let the mess be firmer: if you can add a portion of corn, that which is spoiled, and thus rendered unfit for other purposes, will be found to answer perfectly well. 7. Feed your stock separately, in classes, according to their relative conditions: keep sows in young by themselves; and bacon pigs and porkers by themselves. It is not advisable to keep your stores too high in flesh; for high feeding, however strange it may seem, is calculated to retard development of form and bulk. It is better to feed pigs intended to be put up for bacon *loosely*, and not too abundantly, until they have attained their full stature; you can then bring them into the highest possible condition in an inconceivably short space of time. It is by such a system of management as this that the monstrous swine, their weight exceeding frequently 1200 pounds, or, at all events, half a ton, are raised. 8. Do not neglect to keep your swine clean, dry, and warm. These are essentials, and not a whit less imperative than feeding; for an inferior description of food will, by their aid, succeed far better than the highest will without them. And while I speak of cleanliness, suffer me to reiterate the benefit derivable from washing your pigs; this will repay your trouble manifold.' 9. Watch the markets, and sell when you see a reasonable price before you. To these we may add—when the time arrives for slaughtering, let it be done in a humane and neat style by a butcher, so as to avoid all mangling or injury to the flesh.

[The most approved modes of curing and preparing pork, brawn, bacon, and hams, will be detailed in the number on FOOD—BEVERAGES.]

Diseases.

In a state of nature, the pig is a healthy animal, and even when domesticated, is not readily injured, if treated with anything like common humanity. Cribbed and confined, however; compelled to wallow in filth; exposed indiscriminately to all weathers; now surfeited, and now starved; this day receiving stale food, and to-morrow a diet scalding hot—it is not to be wondered at if the animal should be subjected to the attacks of dangerous and often fatal maladies. The principal diseases to which swine, as thus treated, are liable, are—fever, leprosy, tumours, murrain, measles, foul skin, mange, crackings of the skin, staggers, indigestion or surfeit, lethargy, quincy, inflammation of the lungs, catarrh, and diarrhœa. A large proportion of these, it will at once be seen, is the direct result of want of cleanliness and injudicious feeding, and might be wholly prevented by attending to the directions already given. In cases of fever and other sudden ailments, bleeding, purgatives, and a spare diet, are the safest and surest remedies. Bleeding may be performed by opening the vein behind the ear, or by cutting off a portion of the ears and tail. Castor or linseed oil, Epsom-salts, jalap, and flour of sulphur, are simple purgatives, and can be readily administered in a small mess of enticing food; and when given, should always be followed by a spare and liquid diet. For skin diseases, frequent scrubbings with soap and water, and unguents of tar and sulphur, will be found most effectual. In the case of measles—one of the most common diseases to which pigs are liable—the following recipe has been recommended: Suffer the animal to fast, in the first instance, for twenty-four hours, and then administer a warm drink containing a drachm of carbonate of soda, and an ounce of bole armenian; wash the animal, cleanse the sty, and change the bedding; give at every feeding, say thrice a day, thirty grains of flour of sulphur, and ten of nitre. It is to filthiness, combined with a common fault too little thought of—namely, giving the steamed food or wash to the pigs at too high a temperature—that this troublesome malady is generally to be attributed.

RABBITS.

Rabbits belong to the family *Leporidæ*, members of the *Rodentia* or Gnawing Order of animals. Their form and appearance are too well known to require any special description. In a wild state, rabbits live in holes in the earth; and where the proprietor permits of their accumulation for sport or for sale, they collect in great numbers, undermining with their burrows whole plains or tracts of land, and forming what are called *warrens*. Their amazing fecundity renders the keeping of a few of them in a tame state an object of some consequence in cottage economy. The rabbit litters seven times in the year, and generally produces eight young at a time. At the age of five months, the animal begins to breed; and, taking an estimate perfectly within bounds, it is supposed that a pair of wild rabbits, which breed no oftener than seven times in a year, would multiply in the course of four years to the amazing amount of a *million and a quarter*, if the young were preserved. Many of them die, however, being injured by cold and damp, or are devoured by the male or *buck*.

Experienced rabbit-keepers conceive too frequent breeding to be injurious; but even when proper rules are observed in this respect, three domesticated females (*does*) and a buck will give a family a rabbit for dinner at least twice a week. This is a matter of some consequence. By keeping a few of these pretty little creatures, which wild vegetables will almost entirely supply with food, the poor man may derive ten times the benefit to be gained by violating the laws, and poaching on the game-preserves of his rich neighbours. A stock of rabbits is easily set agoing: they may usually be bought under one shilling, and sometimes even at twopence a pair. It is of importance, in making such a purchase, to attend to the varieties which feed kindly and furnish the best flesh.

The short-legged stout rabbits are generally supposed to be the most healthy, and also the best breeders. The large hair-coloured variety is much esteemed by some people; but the white, or white mottled with black or yellow, are more delicate in flesh. The gray, and some of the blacks, approach nearer to the flavour of the wild rabbit than any others. With respect to the colours of these animals, gray is considered the worst of all colours; black is the next in gradation; fawn, and white and gray, hold the third place in estimation; pure white, with red eyes, is by some reckoned equal with, and by others superior to these; tortoise-shell—a rich brown and white, and brown, gray, and white—and black and white rank the highest; a uniform mouse-colour, though

little noticed by fanciers in general, is much admired by a few.

The most important part of the duty of the rabbit-rearer is to erect his rabbit-house or hutch on proper principles. Two objects are particularly necessary to be attended to. The house or rabbitry must be kept always dry and well aired; because the animal, in its natural state, prefers a dry and airy habitation.

We give a sketch illustrative (fig. 4) of the accommodation and arrangements likely to prove efficient aids in rearing rabbits economically and healthily: *aa* is the line of wall of house against which the rabbitry is supposed to be erected, or it may be in an isolated position; *b* is the principal door by which the rabbitry is entered. The hutches are placed as at *f*, *f*, *g*, *g*, with a passage between; the floor of each hutch must be lined with zinc, or made of asphalt or flag, to prevent the animals burrowing. The hutches for the breeding-does, *g*, *g*, *f*, *f*, should be contiguous to those for the young rabbits, *g'*, *f'*; the partitions between them being capable

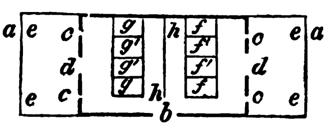


Fig. 4.

of removal; or small doors may be made through which the young rabbits can pass to the breeding-hutches, *g*, *g*, *f*, *f*; or, if necessary, be isolated therefrom. The floors of all the hutches should slope towards the centre of the passage, so as to lead the liquid manure at once to a drain, *h*, *h*, which conveys it away to a small manure-tank. The application of this to the rabbits' recreative-ground, *ee*, *ee*, surrounded by wire-fence, will keep up a fine crop of grass, amongst which they will rejoice. The food is supplied to the hutches through doors opening into the passage. Each hutch should have the front entirely made of wire, to admit plenty of light, which gains admittance through the windows, *c*, *c*; *d*, *d* are the doors through which the rabbits find entrance to the grass-plot, *ee*. Various modifications of this may be made for town-houses, where space is difficult to be had.

On the subject of feeding, the following extract may be offered from the *Boys' Own Book*, a pleasing work addressed to the young: 'If too much food be given at once, the animals will get disgusted with, and refuse it, so that a rabbit may be nearly starved by affording it too great a quantity of food. Most persons feed their rabbits twice, but for our own part we feed ours thrice a day. To a full-grown doe, without a litter, in the morning we give a little hay or dry clover, and a few of such vegetables as are in season; in the afternoon, we put two handfuls of good corn into her trough; and at night, we give her a boiled potato or two, more vegetables, and, if her hutch be clear of what we gave her in the morning, but by no means otherwise, a little more hay or clover. Tea-leaves, in small quantities, well squeezed, may at all times be given, by way of a treat; but it is highly improper to make them a daily substitute for green meat.

'Almost all the vegetables and roots used for the table may be given to rabbits: in preference to all others, we choose celery, parsley, and the roots and tops of carrots; and in this choice the animals themselves heartily agree with us; lettuces, the leaves, and, what are much better, the stumps of cabbages and cauliflowers, they eat with avidity, but these must be given to them with a sparing hand; turnips, parsnips, and even potatoes in a raw state, we occasionally afford our stock, on an emergency, when better roots or good greens are scarce. In the spring-time, no soft meat is better for them than tares, so that they be not wet; in fact, no green meat ought to be given to rabbits when there is much moisture on its surface. We have heard of some country persons feeding their rabbits on marsh-mallows, but we never did so ourselves. Dandelions, milk-thistles, or sow-thistles, we know, by long experience, they take in preference to all other food, except celery, parsley, and carrots; and nothing, as green meat, we are convinced, can be better for them.

'It must be remembered that a doe will eat nearly twice as much when suckling as at other times; and when her litter begin to eat, the allowance of food must be gradually increased.

'If well fed, and kept warm, does will breed all the year; but most fanciers are contented with five litters in one season, and let them rest during the winter. It is a disadvantage, rather than otherwise, to have above six produced in a litter, as the young rabbits, when that is the case, are almost invariably weak and puny; and even if they be reduced to a moderate number, by removing some of them to the care of another doe, or otherwise, they seldom or never become remarkable for their size or beauty.

When rabbits are to be used as food, it is commonly deemed beneficial to feed them for a short time on hay, and afterwards on shellings and oats, when the flesh will grow very delicate in flavour. As an example of the ordinary extent to which rabbits may be made productive, with common care, the case of a labouring man in the country may be mentioned, who, in a small wooden house enclosed by a railing, fed a batch of rabbits, and killed annually about twenty dozen, still maintaining his stock unbroken. What with the skins, flesh, and sales of the young, he turned the animals to good account; yet he scarcely expended a penny upon their food, and even the care of them was spared to him, when he had once fairly put his children in the way of management.

POULTRY.

Poultry (from *poule*, French for hen) is a term applied to different kinds of large birds in a state of domestication; as the chicken or barn-door fowl, turkey, duck, goose, pea-fowl, and guinea-fowl. The most numerous and important in every respect are

Fowls.

The common fowl is classed by naturalists in the tribe of the *Gallinaceæ*, forming part of the order *Rasores* or Scraping-birds (ZOOLOGY). It is needless to describe minutely the appearance of the barn-door fowl. The most prominent characteristics of the cock, or male bird, are a thin indented comb, with wattles on each side under the beak; a tail rising in an arch, and a great variegation of colours. The female, or hen, is smaller as regards body, comb, and wattles, and her tints are less vivid. The domestication of this useful bird seems to have taken place in the earliest times, and Persia is commonly supposed to have been the country of its origin.

Many varieties have been enumerated as existing in Britain; but the differences betwixt these, in the majority of cases, seem to lie as much in colour and size as in any more important features. The best marked varieties are the following: The Dunghill Fowl, Game Fowl, Dorking Fowl, Polish Fowl, Spanish Fowl, Malay Fowl, Hamburg Fowl, Cochin-China Fowl, and Bantam.

The first of these varieties is a mongrel one, arising from crosses with the other breeds. The best fowls of this sort are of middle size and dark colour, and have white, clean legs; the pure white dunghill fowls are held to be the weakest in constitution, and to lay fewest eggs.

It has been usually agreed to call the game fowl the proper English fowl. The body is erect and slender,

and the colours showy, particularly those of the cock. In comparison with other breeds, the Game bird is like the race-horse beside that which draws the cart and plough. The flesh, moreover, is peculiarly white and delicate in flavour, while, though small, the eggs are also of a very superior quality. There is a peculiarity of disposition, however, in this variety of the domestic fowl, which, while for ages the source of a cruel species of sport, has always impaired the real utility of the creature to a very great degree: we allude to the pugnacious spirit which has gained for the fowl its peculiar name. So strongly marked is this propensity, that broods scarcely feathered are found occasionally to have reduced themselves to utter blindness by reciprocal battling. Even when the breed is crossed and recrossed, a tincture of the love of fighting still remains, rendering such admixtures the source of risk and trouble, though in other respects advantageous. Where persons prefer to have a game-cock in their poultry-yard, their choice, according to the best authorities, should be directed to a bird of one or other of the following colours: dark-red, dark black-breasted red, dark-gray, mealy-gray, and reddish-dun.

The Dorking Fowl is named from a town in Surrey, where it has long been bred in great numbers. It is a large bird, well shaped, with a long capacious body, short legs, and five claws upon each foot instead of four. One spur characterises other breeds of the common fowl, but the Dorking fowl has two spurs on each leg. These distinctive marks seem to be of old standing in peculiar breeds, as both Aristotle and Pliny mention five-toed fowls. Though, from repeated crossings, the Dorking fowls are now found of all colours, white or yellowish-white is supposed to have been the primitive and genuine tint. They lay good-sized eggs, and in great plenty. The Cuckoo and Speckled Dorkings are fine birds, and are held in high repute. Within the last few years, there has been a great run upon Cochin-China fowls; but now that this singular taste is abating, Dorkings are every day gaining upon public favour, and are speedily taking up their old position. They are unquestionably the most useful, and perhaps the most remunerative of all the varieties of the domestic fowl. London is supplied with vast quantities of chickens and capons of this breed. The offal is small in comparison to the flesh, which in flavour is justly held as excellent. The shape, size, and beauty of plumage, together with its hatching properties, should recommend the Dorking to the attention of every poultry-keeper. Different kinds should be kept together, as they are found to pine at an early stage when kept unmixed.

The Poland (Polish or Paduan) Fowl is much valued by breeders, but is seldom found perfectly pure in Britain. The species was imported principally from Holland; and when unmixed, was uniformly of a black colour, with a white crest or tuft of feathers instead of a comb, on the heads of both cock and hen. They are now reared in immense numbers in France and Egypt, the eggs being hatched in the latter country artificially. Their form is plump and deep, and the legs of the best sorts not too long. They are called *everlasting* layers, from the number of eggs produced by them, and from their disinclination to sit and hatch, which office is usually done for their eggs by other hens. The three kinds of Polish fowls in greatest repute are the White-crested Black Polish, Silver-spangled, and Gold-spangled.

The Spanish Fowl is of great size, and lays large eggs. It is of the Polish family, and is almost uniformly marked by a black body, dark legs, white cheeks, and large red combs. In London and its vicinity, the breed is now extremely common, being valued for the size of the eggs; but it is supposed to be inferior in some respects to other breeds, though yielding good food.

The Malay Fowl is one of comparatively rare occurrence in poultry-yards, on account of its inutility to the breeder; it is exceedingly pugnacious. They are tall, handsome birds, and certainly make a figure in the poultry-yard; but their flesh does not bear comparison with that of the Dorking fowl.

The Hamburg Fowl is one of the most beautiful of all the Gallinaceous tribe; there are four distinct varieties, as classified at the Birmingham exhibitions—namely, Golden-pencilled, Silver-pencilled, Golden-spangled, and Silver-spangled.

Mr Edward Lowe of Comberford, near Tamworth, whose success in rearing Hamburg fowls gained him the first prize at one of the Birmingham poultry-exhibitions, gives the following results of his experience: 'I find that a hen, now twelve months old, which has laid about five eggs each week since Christmas, weighs exactly three pounds six ounces; and a cock-bird, ten months old, weighs three pounds five ounces. If in good condition, and at full maturity, the cock should weigh at least four pounds, and the hens three and a half pounds each. I have had them at these weights soon after moulting, and before the hens commence laying; but I find them produce such an excessive number of eggs, that they always feel light in hand compared with their apparent bulk, and no amount of food which they are able to take seems sufficient to keep up their flesh. I have never been able to ascertain the *exact* number of eggs that one hen will lay in a year, but I know that some of them have produced more than 200. Under very favourable circumstances, a single hen might produce at least 250; but I should say about 170 would be the average for any given number of fowls. True-bred Hamburgs never shew any inclination to sit; and this, which is considered by many one of their best qualities, might prove a serious difficulty to many poultry-keepers who are not able to keep another sort of hens as incubators. I keep a good many game fowls, and the two sorts work well together, though of course I am obliged to have them on separate walks, as the Hamburgs are very timid, shy fowls, and easily distressed. When the chickens are produced healthy and right, I always find them endure quite as much hardship as any other. For ornamental as well as useful purposes, the Pencilled Hamburg fowls are certainly unrivalled; and I decidedly give the preference to the Golden variety, because they do not shew the dirt in a wet season so much as the Silver. Their plumage is equalled by none, and their symmetry and quality of flesh are only surpassed by the game fowls; and they are the greatest producers of eggs of any breed we have.'

The Hamburg fowl, from its beauty of plumage and tendency to frequent laying, has gradually become a great favourite amongst poultry-fanciers, and is now pretty widely distributed, not only throughout the British Islands, but over the continent of Europe and the United States.

The Cochin-China Fowl, of which so much has been said, and upon which such sums have, within the last few years, been expended, has created a greater sensation amongst all classes of breeders than any other variety of fowl we know of. The great mania was in 1852, when it was not uncommon to hear of £10, £20, or even £50 and upwards being demanded for a good cock and hen; but latterly that extravagant mania has, like many others, in a great measure ceased; and the market-value of the bird is now such as to place it within the range of the humbler classes of poultry-keepers. In the frontispiece of this treatise, we have given sketches of this and a few other of the principal varieties of domestic fowls. The plumage is gay in colour, and soft and yielding to the touch; in size, strength, and weight, it surpasses every other variety; the comb is of moderate size, and notched, and the wattles double; the head is small and narrow, the legs of medium length, and covered with feathers to the toes. It may be said to be all body and no tail or wings, those appendages being almost wanting; hence the

Cochin-China is by no means so graceful an ornament to the poultry-yard as the Hamburg or Dorking varieties.

As a matter of profit, Cochin-Chinas will be found to yield ample returns to the breeder: the hens are excellent sitters, and their fecundity is surprising: they will sometimes lay an egg per diem for several months in succession, and will hatch and carefully rear several broods of chickens annually; the period of sitting and hatching varies between eighteen and twenty-three days.

The Bantam Fowl is well known for its pugnacious habits, its courageous disposition, small size, and feathered grotesque-looking limbs. It was originally a native of India, and the nankeen-coloured and black birds are the most esteemed. The bantam should have a rose-comb, a full tail, and a lively carriage, and should not weigh above one pound. It has been discovered that the characteristic of feathered legs is not an improvement, the birds with clean bright limbs being the best. The flesh and eggs of this diminutive breed are said to be peculiarly delicate and rich.

The chief varieties of the bantam are the Gold and Silver laced, the White, and the Black.

'The black bantam,' says Dickson, 'is a beautiful example of a great soul in a little body. It is the most pugnacious of its whole tribe. It will drive to a respectful distance great dunghill cocks five times its weight. It is more jealous, irascible, and domineering, in proportion to its size, than the thorough-bred game-cock himself. Its combativeness, too, is manifested at a very early period. Other chickens will fight in sport by the time they are half-grown; but these set to work in good earnest. . . . . The black bantam, in his appearance, is a pleasing little fellow. He should have a full rose-comb, clean and sinewy legs, glossy plumage, with almost metallic lustre, of a different tint to the glancing green of the Spanish fowl, arched and flowing tail, waggish impudent eye, self-satisfied air and gait. The hen is of a duller jetty black, is less knowing in her manner, and I think in every way of inferior capacity. These little black hens have great credit for fulfilling their maternal duties well; but I have found them less affectionate and careful than other bantams. They are great stayers at home, prowling very little about, and therefore are desirable in many situations—such as suburban villas that are surrounded by captious neighbours. They will remain contented with the range of a moderate stable-yard, and the least bit of shrubbery; and will do much good by the consumption of numerous insects. They are reputed good layers during winter; but that will depend on the liberality with which they are fed. Cooks say that their eggs, though small, are "very rich," which means, perhaps, that they contain a greater proportion of yolk than those of larger fowls.'

In concluding this condensed description of the various species of domestic poultry, we would only add that they are now considered most profitable stock; where kept in numbers, and carefully attended to, they soon form a considerable addition to the profits of the dairy-farm; and any of the breeds are valuable to the cottager, even one good laying-hen being a treasure to a humble family.

Hen-house.—The artificial assistance given by the cottager in housing the birds is usually of the scantiest order. The upper part of the space at the door of the cottage, or the *baulks* (loft), is often the nightly roost of two or three hens, and the roadside is their daily walk. Yet, with the petty scraps of food furnished in addition to their own pickings there, these hens will lay good eggs, and produce fine birds. At farm-steadings, it is common for the hens to roost among the beams of the stables or cattle-sheds, and to lay in holes formed by scraping away a portion of lime on the top of the side-walls. Very little pains might give to the humblest families much better and ampler accommodation for poultry. We quote on this subject the directions given in a little work by Mr Peter Boswell of Greenlaw: 'To this purpose a part of the space next the roof, so often unoccupied and useless, might easily be devoted. To accomplish the object, a part of it next the kitchen-fire gable-end should be partitioned off, floored, and fitted up with baulks and laying-places. . . . . An opening of sufficient width should be made in the wall, at the height of the lower ceiling, through which the fowls could be conducted by means of a *hen-ladder*, to the enclosure prepared for them below. There must be a hatchway somewhere, to afford access for the purpose of inspection and cleaning. . . . . This is a location for poultry possessing many advantages. Having their berth immediately above the cottage kitchen, they are secured in a proper degree of dryness and warmth, which in winter, especially with the spring-hatched pullets, will tell well in the production of eggs. Perhaps this is the best hen-house locality for securing eggs in winter which can be suggested to the frugal and judicious. Besides, the fowls are here free from many dangers, and safe from many enemies, to which they are exposed in a lower and more open situation.'

The three golden rules to be kept in view by all poultry-keepers, are: *cleanliness*, *warmth*, and *attention*. Without these, the inmates of the poultry-yard can never attain perfection, and, consequently, the breeder will derive only a part, not the whole, of the profit which would otherwise be gained. Every poultry-house should be well cleaned at least once a week, to free it from vermin, hurtful odours, &c. . In farms, and other places where a great stock of poultry is kept, a proper house, with separate accommodation for the different varieties, should be provided; this is a point, moreover, which is rarely attended to. The hen-house should have at least four compartments and a court-yard. The annexed sketch exhibits the requisite accommodation. *a a*, the court-yard; *b b*, for ducks and geese, the apartment for which is at *c*, with laying and hatching-nests, *d*; *g*, the roosting-house for hens and turkeys; *e*, the hatching-house; and *f*, the apartment for laying. Each compartment should be provided with a shutter door, which must be closed every night. If, through inattention, the hen-house should become *tainted*, the health of its inmates will be greatly endangered. A new site should be chosen, and another house erected; or if this be impracticable, the house should be well fumigated, and washed with hot lime-water. The floors should be paved with stone, brick, or tiles; a cheaper kind may be formed of lime, with smith's or common ashes, finely broken and well mixed, and laid on with a trowel.

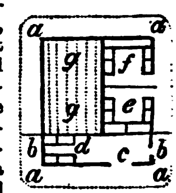


Fig. 5.

The laying-boxes require frequent washing with hot lime-water inside, to free them from vermin which greatly torment the sitting-hens. For the same purpose, poultry should always have a heap of dry sand or fine ashes laid under some covered place, or shady tree, near the yard, to dust themselves in; this being their resource for getting rid of the vermin with which they are annoyed.

The office of keeping and managing domestic fowls should be performed constantly by the same individual, as the voice and presence of a stranger scare them, and disturb the operations of the hen-house. To distribute food and drink at regular hours, to visit the nests, to remove eggs as soon as laid, and carry them to a cool place, to examine by candle-light what eggs are fecundated, and to place these under the hen, and mark the time, are among the daily duties to be performed by the keeper. When the hens lay in a secret corner or covert, the keeper may sometimes discover it by placing a few

grains of salt in the oviduct, which hurries on the process of laying, and causes the animal to retire to the spot anew.

The poultry-house should be built on a sloping piece of gravelly ground, well drained, and, if possible, at a spot which will afford shelter from sun and wind. The roof should be quite weather-tight, as poultry never thrive when exposed either to cold draughts or moisture. The interior should be at least six feet high, for the convenience of the person who cleans the house. The perches should be placed so that the fowls on the top row may not be immediately above those on the second, and so on; a hen-ladder must be provided, but this, like the roosts, should not be too high, as fowls are apt to injure themselves by flying from lofty perches. The floors should be strewn with sand, and should be swept clean every day: those sweepings will be found most useful for the garden. The door should be kept open in fine weather for the sake of ventilation; it should also have a hole at the bottom, with a sliding panel, that the hens may have access to their nests through the day.

Fig. 6 represents a section of a range of pens for the

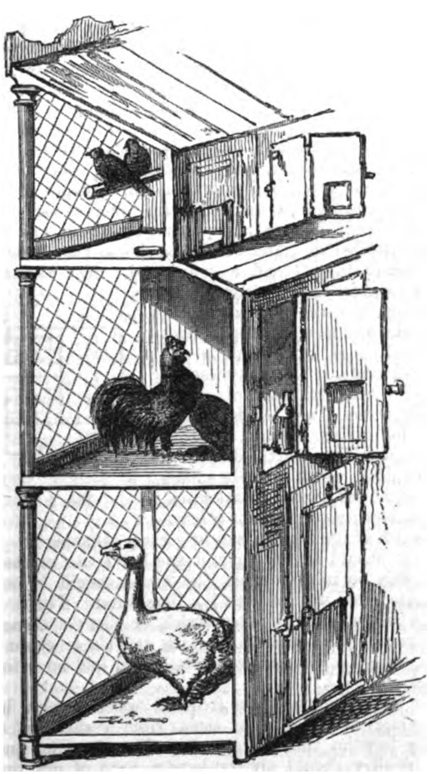


Fig. 6.—Poultry-pen.

exhibition of poultry of the various kinds, constructed on the principle of shewing all the animals of the same species under the same light, and the same conditions generally. The suite of ground-compartments is adapted for geese, ducks, turkeys, rabbits; the next stage is for gallinaceous fowls of the various breeds; and the upper stage is provided with a perch for pigeons, and might also be used for dwarf-fowls. It is a French design.

Feeding.—Most persons are doubtless aware that fowls swallow food without mastication. That process is rendered unnecessary by the provision of a *crop*, an organ which is somewhat similar to the first stomach of the cow, and in which the food from the gullet is macerated, and partly dissolved by secreted fluids. From the crop, the food passes downwards into a second small cavity, where it is partly acted on by a digestive juice; and, finally, it is transferred to the gizzard, or last stomach, which is furnished with muscular and cartilaginous linings of very great strength. In the gizzard, the partially softened food is triturated, and converted into a thin paste, fit to be received into the chyle-gut, and finally absorbed into the circulation. Such is the power of the gizzard in almost all kinds of poultry, that hollow globes of glass are reduced in it to fine powder in a few hours. The most rough and jagged bodies do no injury to the coats of the gizzard. Spallanzani even introduced a ball of lead, with twelve strong needles so fixed in it that their points projected a fourth of an inch from the surface, and the result was, that all the needles, with the exception of one or two, were ground down in a short time to the surface of the ball, while those left were reduced to mere stumps. It is remarkable that, to add to the triturating powers of the gizzard, fowls are gifted with the instinct of swallowing gravel with their food.

Fowls, when left to roam at large, pick up all sorts of seeds, grains, worms, larvæ of insects, or any other edible substances they can discover, either on the surface of the ground or by scraping. They also pick a little grass as a stomachic. The more that hens can be allowed to run about to gather their food, the better for their health and the pockets of their keeper. When secluded, and fed altogether in an artificial manner, their keep becomes expensive, and is, on the whole, seldom compensated by their produce. We have indeed great hesitation in advising any one to keep fowls who cannot inexpensively give them plenty of refuse from the table, or permit them to range in a field or lane in quest of what seems proper for their natural appetite. The very pleasure of ranging and scraping seems advantageous to them.

If kept in a court-yard or pen, and requiring altogether artificial feeding, their natural tastes should be consulted as far as conveniently practicable. They should be fed regularly, and with a miscellaneous kind of diet; allowed at all times access to clean water for drinking, and have earth, sand, or dust to scrape at pleasure and roll themselves in. A certain quantity of chalk or lime should also be scattered about for them to pick up, as that material is required by them in the production of eggs. Speaking on this subject, Professor Gregory of Aberdeen, in a letter to a friend, published in a newspaper, observes: 'As I suppose you keep poultry, I may tell you that it has been ascertained that, if you mix with their food a sufficient quantity of egg-shells or chalk, which they eat greedily, they will lay, other things being equal, twice or thrice as many eggs as before. A well-fed fowl is disposed to lay a vast number of eggs, but cannot do so without the materials for the shells, however nourishing in other respects her food may be; indeed, a fowl fed on food and water free from carbonate of lime, and not finding any in the soil, or in the shape of mortar, which they often eat off the walls, would lay no eggs at all, with the best will in the world.'

In a state of domestication, the hard food of which fowls seem most fond, are peas, barley, oats, &c.; and besides a proportion of these, they may be given crumbs of bread, lumps of boiled potatoes, not too cold, cabbage, turnips chopped small, &c. They are much pleased to pick a bone; the pickings warm them, and excite their laying propensities. If they can be supplied with caterpillars, worms, or maggots, the same end will be served. Any species of animal food, however, should be administered sparingly; and the staple articles of diet must always be of a vegetable nature. They should be fed three times a day. When wanted for the table, the quantity of food may be increased, and be more substantial; they should also be kept more within the coop,

and as quiet as possible. A fortnight's feeding in this way will bring a fowl of a good breed up to a plump condition.

Laying.—The ordinary productiveness of the hen is truly astonishing, as it usually lays, in the course of a year, 200 eggs, provided it be allowed to go at liberty, is well fed, and has a plentiful supply of water. Many instances have been known of hens laying 300 in a year. This is a singular provision in nature, and it would appear to have been intended peculiarly for the use of man, as the hen usually incubates only once in a year, although she will occasionally bring out two broods. Few hens are capable of hatching more than from twelve to fifteen eggs; so that, allowing they were all to sit twice a year, and bring out fifteen at a time, there would still be at least 170 spare eggs for the use of man. It is therefore evident that, in situations where hens can pick up their food, they must prove very profitable; for, supposing that the eggs of one fowl during the year were sold, without any of them being hatched, they would bring, if near a large city, on an average, 9d. per dozen, or 14s., and the hen herself would be worth 2s. at least. As the number of eggs which are annually brought out by a hen bear no proportion to the number which she lays, schemes—to be subsequently noticed—have been imagined to hatch all the eggs of a hen, and thus turn her produce to the greatest advantage; so that in place of twelve or fourteen chickens, upwards of 200 may be produced from the annual produce of a single fowl.

Hens will lay eggs which have received no impregnation, but from these, as a matter of course, no hatching can take place; they are equally good, however, for eating. When the chief object is to breed chickens, a cock should be allowed to walk with ten or twelve hens; but when eggs are principally required, the number of hens may be from fifteen to twenty. Endeavour to procure a cock of a good breed, not game, and let him be in his prime, which is at eighteen months to two years old. Cocks will last two years, after which they lose their liveliness of colours, and become languid, inactive, and mere consumers of food. It is fit, therefore, that younger cocks should then take their place in the poultry-yard. It is common to make choice of a young cock, by pitting one or two against each other, and selecting the most courageous, which is always sure to be the favourite of the yard.

Some remarks have been made on the colours of the best hens of the different varieties. As to other qualities, M. Parmentier recommends that they should be chosen of a middling size, robust constitution, large head, bright eyes, and pendent comb. Crowers should be rejected, and those that are of quarrelsome tempers, such hens being rarely good hatchers or layers. Old hens, or those above five years old, are of little use when added to a stock; and when the comb and claws are rough, it is a sign that they have ceased to lay.

If left to themselves, hens would produce, like some wild birds, two broods in the year. Early spring, and, after a cessation, the end of summer, are the two seasons in which they begin naturally to lay. In the depth of winter, under ordinary circumstances, hens very rarely lay eggs, though by artificial means they can be made to do so. If the temperature of the place where they are kept be raised by a stove, or otherwise, they will produce eggs. The fowls of the Irish peasantry, which are usually kept in the cabins of the owners, lay often in winter, in consequence of the warmth of their quarters; and there can be no doubt that warmth affords the most effective means of procuring new-laid eggs in winter, though stimulating food may aid in producing the same result. The fecundity of hens varies considerably. Some lay but once in three days, others every second day, and others every day. In order to induce laying, each hen should have its own nest, made with soft straw or heather, and furnished with a piece of chalk as a decoy or *nest-egg*. The signs which indicate when a hen is about to lay are well known. She cackles frequently, walks restlessly about, and shews a brighter redness in her comb and wattles. After the process of laying is over, she utters a series of loud and peculiar notes, to which the other fowls usually respond. Shortly after the egg is laid, it should be removed, for the heat of the hen soon corrupts it. When the eggs are taken away by the poultry-keeper, they should immediately be laid in a cool and dry place. If allowed to absorb damp, they soon spoil; indeed one drop of water upon the shell quickly taints the whole egg.

Various methods have been tried to prevent the absorption of air through the shell, and preserve the freshness of the eggs. A not uncommon plan is to keep them secluded from the air in bran, rye, or ashes, which may do very well where the eggs are to be kept in this way till eaten, but is utterly useless if quantities of them have to be sent to market. We beg to offer a plain piece of advice to cottagers on this subject, which, if properly acted on, will give them the means of at all times commanding the highest price for *fresh eggs*, although situated a hundred miles or more from the place of sale. *Smear all your eggs with a bit of fresh butter the moment you get hold of them.* Do not load the shell with grease, but merely give a light varnish. The butter must be good. By this simple process of smearing, which does not taint the interior in the slightest degree, the egg is as fresh at the breakfast-table, and possesses all the delicious milkiness when three months old, as if just newly laid. Scarcely anything is more common than to hear complaints of the difficulty of getting fresh eggs, and all a result of the sheer negligence of fowl-keepers. By the plan we mention, there need rarely be such a thing as a bad egg heard of. Dipping in lime-water and some other processes are said to be equally effectual.

Hatching.—When eggs are to be hatched, it is necessary to pay attention to the choice of proper ones for the purpose. The company of the male bird renders the hen productive of fecundated eggs; and, as already noticed, it is only eggs of this kind that are available for producing young. The eggs must also be fresh; from the time they are laid, they should lie aside in a cool place. It is said to be possible to ascertain, from the appearance of the egg, whether the forthcoming progeny is to be male or female. When eggs are left to be brought forth by the hen, a certain number are placed under her in the nest, when she is in the full inclination to sit. From nine to twelve eggs are placed, according to the extent of the breast and wings; and the time required for hatching is about twenty-one days. Sometimes a hen will desert her eggs, a circumstance which may occasionally be traced to an uncomfortable condition of the skin, caused by vermin or want of cleanliness; and this affords a strong reason for keeping the hen-house clean, and giving the animals the means of purifying their feathers. Occasionally, the hen is vicious, or, in short, a bad sitter, and experience in pitching on the best hatching-hen is the only remedy. Sometimes a hen will break her eggs with her feet; and in such cases the broken eggs must be removed as soon as observed, otherwise she may eat them, and from that be tempted to break and eat the sound ones, and thus spoil the whole.

It has generally been found that hens which are the best layers are the worst sitters. Those best adapted have short legs, a broad body, large wings, well furnished with feathers, their nails and spurs not too long or sharp. The desire to sit is made known by a particular sort of clucking note, or, as it is termed in Scotland, *kloking;* and a feverish state ensues, in which the natural heat of the hen's body is very much increased. The inclination, or, as physiologists term it, the *storge*, soon becomes a strong and ungovernable passion. The hen flutters about, hangs her wings,

bristles up her feathers, searches everywhere for eggs to sit upon; and if she finds any, whether laid by herself or others, she immediately seats herself upon them, and continues the incubation.

With a proper provision of food at hand, warmth, quiet, and dryness, a good hatching-hen will give little trouble, and in due time the brood will come forth; one or two eggs may perhaps remain unhatched or addled, but their loss is of little consequence. As soon as the hen hears the chirp of her young, she has a tendency to walk off with them, leaving the unhatched eggs to their fate. It is therefore advisable to watch the birth of the chicks, and to remove each as soon as it becomes dry, which may be in a few hours afterwards. By this means the hen will sit to hatch the whole; yet she should not be wearied by too long sitting. If all the eggs are not hatched at the end of twelve or fifteen hours after the first chick makes its appearance, in all probability they are addled, and may be abandoned. The chicks must be kept in a warm place during the first day, and at night restored to the mother, who now assumes her maternal duties. The food given to the young chicks should be split grits, which they require no teaching to pick up; afterwards the ordinary food of the poultry-yard, or what the mother discovers for their use, is sufficient. Some give the yolks of hard-boiled eggs or curd, when a nourishing diet seems advisable. The extreme solicitude of the hen for her young, or the brood which may be imposed upon her, is well known. She leads them about in quest of food, defends them by violent gesticulations and the weapons which nature has given her, calls them around her by a peculiar low clucking cry, and gathers them carefully under her wings, to shelter them from danger or to keep them warm at night. This maternal care is bestowed as long as the chickens require her assistance; as soon as they can shift for themselves, the mutual attachment ceases, and all knowledge of each other is very speedily lost. The young now go to roost, and the mother again begins to lay. Young hens, usually called pullets, begin to lay early in the spring after they are hatched.

Artificial Hatching.—As heat is all that is necessary to develop the chick in the egg, eggs may be hatched artificially, without the intervention of the hen. The art has long been practised in Egypt, and has since been adopted in many other quarters, but with indifferent success. In the variable and moist climate of Great Britain, at least, there is little chance of Eccaleobions, or Patent Incubators, ever superseding, to any great extent, the office of the brooding-hen.

Capons.—The best modes of fattening fowls for the table have been adverted to. The process of converting chickens into capons, however, ought also to be noticed here. By removing the reproductive and oviparous organs from the male and hen chickens respectively, a great change is produced in them as regards voice and habits, and they can be made remarkably fat for the table. Capons are chiefly reared in Sussex, Essex, and one or two other counties around London. They can be trained to watch chickens, hatch eggs, and do many useful offices of the poultry-yard. Upon the whole, however, the special benefit derived from rearing capons does not counterbalance the trouble which they give and the danger of the primary operation; for an account of which, as practised in different countries, see Dickson on Poultry.

Diseases.—Chickens are liable to various diseases, demanding attention from the poultry-keeper. The *pip* is the most common; it consists of a catarrhal thickening of the membrane of the tongue, causing a dangerous and obvious obstruction to respiration. It may be cured in most cases by throwing the fowl on its back, holding open the beak, and scraping or peeling off the membrane with a needle or the nail. The part may be wetted with salt or vinegar afterwards, and a little fresh butter pushed over the throat. Dr Bechstein recommends giving a mixture of butter, pepper, garlic, and horse-raddish, as an internal remedy. But the operation is most effective. *Thirst* sometimes attacks fowls like a fever, and often arises simply from dry food, though more frequently symptomatic of indigestion or some internal and deep-seated derangement. Careful attention to diet is the first and great point in all such cases. If *constipation* appear to be present, bread soaked in warm milk, boiled carrots or cabbages, earth-worms, chopped suet, or hot potatoes with dripping, will be found useful. A clyster of sweet oil should be tried in severe cases. Where a tonic seems to be required, a little iron-rust may be mixed with the food, and will generally relieve atrophy or loss of flesh. Where diarrhœa or scouring is observed, iron or alum may be given in small quantities. There is also a species of influenza called the *roup*, which is often epidemical in the poultry-yard, and causes much havoc among the young birds. The eyes become swollen, a discharge comes from the nostrils, and the fowl gapes continually, shewing much difficulty of breathing. Some observers have ascribed this complaint to worms in the windpipe, and have recommended their extraction by an operation; but warmth, cleanliness, soft food, and such laxatives as sulphur, with frequent ablutions of the eyes and nostrils, are more likely, perhaps, to do good, and are not attended with danger. Where general fever has been observed in fowls, the use of a little nitre has been found very advantageous. Saffron is another remedy very often employed in relieving the symptoms of sickness in fowls.

Many of these remarks will apply equally well to the diseases of geese and the other species of domestic poultry yet to be noticed; and this subject, therefore, need not again be adverted to in detail.

Turkeys.

The turkey, like the common fowl, has been included by naturalists in the *Gallinaceous* family of birds, and possesses the main characteristics common to the whole. It is a native of the woods of North America, and is certainly one of the most valuable fowls which have been naturalised in this country, but is very difficult to rear. The turkey-hen lays from fifteen to twenty eggs, and then sits upon them. She will bring out two broods in a year. The eggs are of a pale yellowish-white colour, finely streaked and spotted with reddish-yellow. They are a most delicious food, much more delicate in their flavour than those of the common hen. In England or Scotland, however, the eggs are comparatively seldom to be met with for sale, being deemed too valuable to be used as food. In Ireland, they are to be got in the markets in great abundance, especially in the midland counties, where we have bought them at ninepence per dozen. In that country, when the hen has laid about half-a-dozen eggs, they afterwards take away one daily, by which means the hens are induced to produce a greater number of eggs than otherwise. This they assist by means of stimulating food, such as hemp-seed and buckwheat. There is an interval of a day between the laying of each egg. It is said that the first two eggs which she lays are unfruitful. A turkey-hen can seldom hatch more than from sixteen to eighteen eggs. The time of incubation varies from twenty-seven to twenty-eight days, at which time the young begin to pierce their shelly prison, and emerge from it.

General Treatment.—When turkey-chicks first come forth, they are extremely weak, and much assiduous care is necessary to rear them. The first thing to be attended to is, to remove them to a situation where they are not exposed to the sun's rays, which at first are too powerful for them. A woody place is the most suitable to their natural habits. Nothing is so destructive to them as rain, from which they must be protected. When young turkeys accidentally get wet, they should be brought

into a house, carefully dried by applying soft towels to them, and then placed near a fire, and fed upon bread which has been mixed with a small proportion of ground pepper or ginger. It should be made up in the form of small peas. If the bread is too dry for this purpose, it may be moistened with a little sweet milk. Should the turkey-poults refuse to eat it, a few of these pellets may be forced down their throats. Even heavy dews prove destructive to them, and frost is no less injurious in its effects. These must, therefore, be most carefully guarded against when the hens incubate in March or early in April. Dry and sandy situations are most congenial for breeding turkeys, and especially elevated situations where large woods are contiguous. A single male turkey is sufficient for twelve or sixteen females, although the former number is probably the safest, to prevent sterility in the eggs, which is frequently the case with those of turkeys. Eggs should never be intrusted to the care of a female until she is at least two years of age, and they may be kept for the purpose of incubation till they reach their tenth year. The largest and strongest hens should always be kept for this purpose. During the time the hen is sitting, it becomes necessary to place food near her; otherwise, from her assiduity, she may be starved to death, as turkey-hens seldom move from their nest during the whole time of incubation.

Where farmers rear turkeys in great numbers, they do not indulge the hen by allowing her to sit as soon as she has done laying, but keep them from her until all the other hens have ceased to lay, as it is of consequence that they should all be hatched about one time. When hens are unhappy during this interval, they may be indulged with hens' eggs. When they have all ceased to lay, each of them is provided with a nest ranged close to the wall, in a barn or other convenient place, and each is supplied with from sixteen to twenty of her own eggs. The windows and doors are then closed, and only opened once in the twenty-four hours for the admission of air, and for the purpose of feeding the hens. They are taken off their nests, fed and replaced, and again shut up. On the twenty-sixth day, the person who is intrusted with the management of the birds examines all the eggs, and removes those that are addled; feeds the hens, and does not again disturb them till the poults have emerged from their shells, and have become perfectly dry, from the heat of the parent bird: to be subjected to cold at this time would certainly kill them. When the young birds are thoroughly dried, two of the broods are joined together, and the care of them intrusted to a single hen; and those which have been deprived of their offspring are again placed on hens' or ducks' eggs, and subjected a second time to the tedious operation of incubation, in which case it is not unusual for them to bring out thirty eggs. We cannot recommend this practice in point of humanity; for the poor hens, when they have accomplished their second sitting, are literally reduced to skin and bone, and frequently so weak as hardly to be able to walk.

As before hinted at, great care should be taken of the young turkey-poults; besides warmth, proper food and shade, the nearer they are to a pure running stream the better, as they drink a great deal; and nothing is of greater importance to their being successfully reared than fresh drink. They must be also carefully protected from strong gusts of wind, and on the slightest appearance of a thunder-storm, should be immediately taken into a house. They should get no food for twenty-four hours after they leave the egg. Their first food should be hard-boiled eggs finely chopped, and mixed with crumbs of bread. Curd is also an excellent food for them. When they are about a week old, boiled peas and minced scallions are given to them. If eggs are continued, the shells should be minced down with their food, to assist digestion, or some very coarse sand or minute pebbles. They should be fed thrice a day; and as they get older, a mixture of lettuce-milk will be found beneficial, together with minced nettles. Barley boiled in milk is another excellent food at this period, and then oats boiled in milk. In short, the constitution of young turkeys requires at all ages every kind of stimulating food. When about three weeks old, their meat should consist of a mixture of minced lettuce, nettles, curdled milk, hard-boiled yolks of eggs, bran, and dried chamomile; but when all these cannot be readily obtained, part of them must be used. Fennel and wild endive, with all plants which are of a tonic character, may be safely given to them. Too much lettuce, however, has been found to be injurious. When poults are about a month old, they should be turned out, along with the parent bird, into the fields or plantations, where they will find sufficient food for themselves. Grass, worms, all kinds of insects and snails, are their favourite food, and nature dictates to them such vegetables as are conducive to their general health. As their feet are at first very tender, and subject to inflammation from the pricking of nettles and thistles, they ought to be rubbed with spirits, which has the effect of hardening the skin, and fortifying them against these plants.

The glandulous fleshy parts and barbles of their heads begin to develop when they are from six weeks to two months old. This is a critical period with the poults, and unusual care must be bestowed on them, as they now become weak, and often sickly. A little brine mixed with their food will be found very beneficial, or spirits much diluted with water. A paste made of fennel, pepper, hemp-seed, and parsley, has been found an excellent remedy when afflicted with an inflammation in the wattles, to which they are liable when growing. They are very subject to this if the weather happens to be broken and changeable at the time these tubercles are growing. These parts swell and grow very red, which frequently proves fatal to them. If, therefore, such be the state of the weather at this critical period, the paste above recommended should be given although they are perfectly healthy, which will be found an excellent preventive. When the inflammation becomes very great, recourse is often had to bleeding in the axillary vein, which frequently has the effect of recovering them.

Soon after the turkey-poults have acquired their first feathers, they are liable to a disease which is very fatal to them, if not attended to. This distemper produces great debility, and the birds appear languid and drooping, and almost totally neglect their food. Their tail and wing-feathers assume a whitish appearance, and their plumage has a bristled aspect. This is occasioned by a disease in two or three of the rump-feathers. On examination, the tubes of these will be found filled with blood. The only remedy for this disease is to pluck them out, when the bird will speedily acquire its wonted health and spirits.

In fattening turkeys for the table, various methods are resorted to. Some feed them on barley-meal mixed with skim-milk, and confine them to a coop during this time; others merely confine them to a house; while a third class allow them to run quite at liberty; which latter practice, from the experience of those on whose judgment we can most rely, is by far the best method. Care should, however, be taken to feed them abundantly before they are allowed to range about in the morning, and a meal should also be prepared for them at midday, to which they will generally repair homewards of their own accord. They should be fed at night, before roosting, with oatmeal and skim-milk; and a day or two previous to their being killed, they should get oats exclusively. We have found from experience that when turkeys are purchased for the table, and cooped up, they will never increase in bulk, however plentifully they may be supplied with food and fresh water, but, on the contrary, are very liable to lose flesh. When feeding them for use, a change of food will also be found

beneficial. Boiled carrots and Swedish turnips, or potatoes mixed with a little barley or oat meal, will be greedily taken by them. A cruel method is practised, chiefly on the continent, to render turkeys very fat, which is termed cramming. This is done by forming a paste of crumbs of bread, flour, minced suet, and sweet milk, or even cream, into small balls about the bulk of a marble, which is passed over the throat after full voluntary meals. The liver of those turkeys, prepared in a peculiar way, forms the *pâté de foie gras* of epicures.

Pea-fowl.

The peacock, also one of the gallinaceous tribe of birds, came originally, it is said, from India, and was well known to the ancient Greeks and Romans, who introduced it into their mythology. The great beauty of its tail, so ample in extent and so rich in colours, rendered it indeed not unworthy of such preferment.

One peacock is usually kept with three or four hens. The female is extremely fastidious about a spot to lay in, and generally leaves any artificial nest for the grass of some neighbouring coppice, where she lays under the branches of a shrub, in a well-concealed situation. One reason for this is the propensity of the cock to break the eggs if he discover them. When the eggs of the peahen are gathered in sufficient numbers, whether from a natural or artificial nest, it is a common practice to place them under a common hen, which hatches them in thirty days, and makes an excellent stepmother to the young chicks. These are very tender at first, but soon grow vigorous, even in a chilly climate. Barley-meal paste, mixed with cheese or curd prepared from milk, with alum, ants' eggs, meal-worms, and hard-boiled egg, are among the common articles of diet given to the young. The grown-up pea-fowl feeds on boiled barley or other common grains, and is a dangerous visitor of corn or wheat fields and gardens. On the other hand, they are voraciously fond of such creatures as frogs, lizards, and the like, and keep grounds clear of such annoyances. In moulting-time, it is requisite to be more careful of these fowls than at other times, and to give them good grain, with a little honey and fresh water. Though the tongues and livers of peacocks were ranked among the dainties of the Roman epicures, the bird is rarely killed for table now a days. Yet it always bears a high price, being one of the most beautiful of the feathered race, and an object on which the eye ever delights to dwell, though its screaming note by no means gives a corresponding pleasure to the ear.

The Guinea-fowl.

This stranger is found native in Africa, as its name indicates, and it also exists in an indigenous state in South America. The Guinea-fowl (*Numidia meleagris*) is about the size of the common hen, and the male differs very little in appearance from the female. Three species exist in considerable numbers in Europe—namely, the crested, the mitred, and Egyptian varieties. A very beautiful sort is marked by a pure white tint of body, but the most familiar hues are dark-gray and black. The bird is less tame than other common poultry, and prefers to live in a half-wild condition in its native regions, perching and living on trees like undomesticated birds. It is a spirited creature, and will battle even with the turkey. Guinea-hens require great attention at the time of laying, making their nests by preference in corners of the woods. Their eggs are small, but much esteemed; and the common hen is usually made to rear their broods. In the market, guinea-fowls always bear a high price, both on account of their flesh, which is of a good quality, and because they form a very pretty variety of the poultry stock. Their food is grain, of the various kinds given to ordinary barn-door fowls, with which they assimilate closely in habits. On the whole, they may be said to be kept more from curiosity than for profit.

The Goose.

The goose differs in many respects from the fowls already noticed, being aquatic in its habits. It is marked by a flat bill and webbed feet, characters also possessed by the duck and swan, which, in conjunction with the goose, may be held as forming a distinct family (*Anatidæ*) of the feathered aquatic tribes.

Our common tame goose is the wild species domesticated, known to naturalists by the name of the fen or stubble goose. Where people have a right of common, or live in the vicinity of marshy heaths, the breeding and rearing of geese will prove very profitable, for in such situations they are kept at a trifling expense; they are very hardy, and live to a great age. If properly kept, and fed regularly, although sparingly, they will lay upwards of 100 eggs yearly. If these are set under large hens, each having half-a-dozen, with the assistance of the goose herself, they may be nearly all hatched. For the first three or four days, they must be kept warm and dry, and fed on barley-meal or oatmeal mixed with milk, if it is easily procured; if not, let these ingredients be mixed with water. They will begin to grow in about a week. For a week or two the goslings should not be turned out till late in the morning, and should always be taken in early in the evening. In Ireland, the tenantry depend much on the breeding of these birds and turkeys to pay their rent; and with those who are industrious and favourably situated for rearing geese, they even do more in many instances. In the early part of the year, they are allowed to feed on grass, on heaths, meadows, commons, and roadsides; and as most of the peasantry have small bits of corn-land of their own, the geese are turned out on the stubble to pluck what grass is left; and they also fatten upon it, and improve the flavour of their flesh.

Although water be the natural element of geese, yet it is a curious fact that they feed much faster in situations remote from rivers and streams. To fatten geese, it is necessary to give them a little corn daily, with the addition of some raw Swedish turnips, carrots, mangel-wurzel leaves, lucerne, tares, cabbage leaves, and lettuces. They should not be allowed to run at large when they are fattening, as they do not acquire flesh nearly so fast when allowed to take much exercise. Therefore those who can only afford to bring up a goose or two, should confine them in a crib or some such place about the beginning of July, and feed them upon the ingredients above recommended, with a daily supply of clean water for drink. If, on the contrary, from a dozen to twenty are kept, a large pen of from fifteen to twenty feet square must be made, and well covered with straw in the bottom, and a covered house in a corner for protection against the sun and rain when required, because exposure to either of these is not good. It will be observed that about noon, if geese are at liberty, they will seek some shady spot, to avoid the influence of the sun; and when confined in small places, they have not sufficient room to flap their wings and dry themselves after being wetted; nor have they room to move about so as to keep themselves warm. There should be three troughs in the pen, one for dry oats, another for vegetables—which ought always to be cut down—and a third for clean water, of which they must always have a plentiful supply. It must be remembered that the riper the cabbages and lettuces with which they are supplied, the better. In the neighbourhood of large towns, the most profitable way of disposing of geese is in a dead state; as nearly the same sum can be obtained for them as if they were alive; and then you have the feathers, which are valuable, and may be sold to much advantage by themselves when you have collected a stone-weight or more.

Geese are kept in vast quantities in the fens of Lincolnshire, several persons there having as many as 1000 breeders. They are bred for the sake of their quills

and feathers, as well as for their carcass; it is therefore customary to strip them partially of the fine downy feathers, and leave them to grow afresh, and also to take quills from their wings—both practices barbarous in the extreme, however they may be attempted to be justified. Geese breed in general only once a year, but if well kept, they sometimes hatch twice in a season. The best method for promoting this is to feed them with corn, barley, malt, fresh grains, and, as a stimulant, they should get a mixture of pollard and ale. During their sitting, each bird has a space allotted to it, in rows of wicker-pens placed one above another, and the goose-herd who has the care of them, drives the whole flock to water thrice a day, and bringing them back to their habitation, places every bird—without missing one—in its own nest. One gander is generally put to five geese. The time of incubation varies from twenty-seven to thirty days. The goose begins to lay in March, but the time of the month depends upon the state of the atmosphere. When goslings are first allowed to go at large with their dam, every plant of hemlock which grows within the extent of their range should be pulled up, as they are very apt to eat it, and it generally proves fatal to them. Nightshade is also equally pernicious to them, and they have been known to be poisoned by cropping the sprigs of the yew-tree.

Ducks.

Ducks are easily kept, particularly near ponds or streams of water. In such situations, even the poorest families may have half-a-dozen of them running about without the least inconvenience. In keeping them in a domestic state, one drake is usually put to half-a-dozen ducks. The ducks begin to lay in February; their time of laying being either at night or early in the morning. They are extremely apt to deposit their eggs in some sequestered spot, and to conceal them with leaves or straw. From eleven to fifteen eggs is the number which a duck can properly cover. The time of incubation is about thirty-one days. The place where they incubate should be as quiet and retired as possible; and if they have liberty, they will give no trouble whatever in feeding, as the duck, when she feels the call of hunger, covers her eggs carefully up, and seeks food for herself, either by going to the streams or ditches in her neighbourhood, or, if such are not at hand, she will come to the cottage and intimate her wants by her quacking. When the young are hatched, they should be left to the care of the duck, which will lead them forth in due time; and when she does so, prepare a coop for them, which should be placed on short grass, if the weather is mild; and if cold or stormy, they should be kept under cover. The future strength of the brood will depend much upon the care that is taken of them for the first three or four weeks after they have emerged from the shell. Ducklings will begin to wash themselves the first day after they are hatched, if they find water at hand; therefore a flat dish filled with that element should be always within their reach. Many persons are in the practice of clipping the tail, and the down from beneath it, in ducklings, if the weather is wet during the first weeks of their existence. This is to prevent them from draggling themselves, which has a tendency to produce intestinal diseases. From a fortnight to three weeks is all that is necessary to confine them to the coop.

The first thing on which ducklings are fed is a mixture of barley, peas, or oat meal, and water. They may afterwards be fed upon a mixture of buckwheat, and any of the above-named meals. The greatest attention must be paid to keeping their bed warm and dry; and with young ducks, a frequent change of straw is absolutely necessary, as their beds soon get dirty, wet, and fetid.

Ducks are not such attentive guardians of their young as hens, and therefore it is a common practice to place duck-eggs under a sitting hen, and leave her to hatch them as her own progeny. When the young ducks so hatched make their appearance, the hen does not appear aware of the imposition, but takes at once to her duties with all a mother's fondness. The natural desire of the ducklings to plunge into water and swim away from the shore vexes her, but she watches for their return, and does all in her power to provide the means of subsistence. She scrapes for them, which a duck would not; she shelters them under her dry and warm bosom and wings, and altogether makes a better nurse than their own proper parent.

In feeding ducks for use, peas and oat meal are to be preferred. It is said that barley-meal renders their flesh soft and insipid. Bruised oats should be given to them freely for some weeks before they are killed, which renders their flesh solid and well tasted; and the same general principles recommended in the feeding of geese should be kept in view. It has been found that the offal of butchers' shops feeds ducks quickly, and that this does not impair the flavour of their flesh. In very many instances, ducks are reared in situations where there are no pools of clean water for them to dabble in, and the poor animals are compelled to grub with their bills in all sorts of nauseous puddles, which of course makes their flesh rank and offensive. They should in all cases have a pool of clean water to swim in, and are best reared near a natural meadow, lake, or pond, where they can search for their appropriate food.

Those who have paid much attention to the management of domestic poultry, assert that geese and ducks should be kept apart from other fowls. The former should have their houses ranged along the banks of a piece of water with a fence, and sufficiently extensive for walks in front, with doors for their access to the water, which can be closed at pleasure.

Swans.

Swans are generally kept for ornament rather than use. The flesh, even of the young, is black, hard, and rank, while that of the old is too tough for mastication. The eggs also are not peculiarly palatable; and there is little inducement to rear them, in short, if mere pecuniary advantage be looked to, excepting on the score of the skin, feathers, and down, which are articles of considerable value. At the same time, if the swan be not a productive bird, few animated objects can be compared with it as regards ornament. Its great size, snow-white plumage, and graceful form, render it a most attractive spectacle upon the bosom of a pool or lake. It is a hardy, long-lived fowl, and associates in pairs. The food of the swan consists usually of seeds, roots, and plants, rendered succulent by water. When fed in a barn-yard, it seldom thrives, being more decidedly aquatic in its habits than ducks or geese. From the colour of the European swan being so uniformly white, a black swan used once to be proverbially spoken of as an impossibility; but black swans occur abundantly in Australia, from whence they are now frequently brought, as curiosities for the pleasure-ponds of the wealthy.

Pigeons.

Pigeons are among the most ornamental and useful appendages of a rural dwelling. If permitted to fly abroad to seek their food, little expense will be incurred for their keep, while the value of their young will be of some importance to cottagers. The pigeon has a great power of flight, and will go to a distance of many miles in quest of the means of subsistence; but wherever it may fly, it never fails to return home. The leading features of the district around its habitation appear to be impressed on its memory; and flying at a great height, and with a wonderful power of vision, it sees the well-remembered landmarks, and directs its path homeward. This habit of seeking for the place at which it was reared, makes it difficult to keep pigeons in any new home; the best plan of inducing them to settle in

a new abode is to clip one wing, which prevents their flying, and keep them in a cot near the ground till they get accustomed to the place.

Many persons keep their pigeons in the space between the garret and roof of their dwelling-house, with holes at which they go out and in; and this arrangement answers very well, for the animal's lodging must be dry and comfortable. A more regular plan is to furnish them with a properly constructed dove-cot, aloof from any building. The cot should consist of a substantial wooden box, with a sloping roof, and divided interiorly by partitions into as many cells as pairs are to be kept, for each pair requires a distinct cell. Each compartment should be twelve inches deep from front to back, and sixteen inches broad; the entrance-hole should not be opposite the centre of the cell, but at a side, so that the pigeons may build their nest a little out of sight. In front of each cell there should be a slip of wood to rest and coo upon; but as different pairs incessantly quarrel about the right of walking on these slips, and are apt to fight for the possession of cells, it is best to separate the slips with upright partitions; and it would be an improvement to have two or three small cots instead of one large one. The cot, of whatever size or form, should be elevated on a wall facing the south-east, or otherwise placed at such a height as will be out of the reach of cats and other vermin. The cot should be painted white, as the pigeon is attracted by that colour. Gravel should be strewed on the ground in front of the dove-cot, the birds being fond of picking it; and a little straw or hay is necessary for the nests. Cleanliness is indispensable to the health of the birds, and a scouring out of the cot should therefore take place regularly. The quantity of dung produced in the nests is very great, and its removal to the compost heap will amply repay the trouble of cleaning.

In commencing to keep pigeons, a pair or two should be procured which have not flown, and they should be shut up for a time, and well fed. Their chief food is grain, and the kind which they prefer to all others is dried tares. Small horse-beans are another favourite article of diet, and very nutritious to them. Wheat, barley, oats, and peas, with rape, hemp, and canary seeds, are also prized by them, but should not be made constant articles of food under any circumstances.

The house-dove, or common pigeon, as is well known, begins to breed about the age of nine months, and breeds every month. During breeding-time, they associate in pairs, and pay court to each other with their bills; the female lays two eggs, and the young ones that are produced are for the most part a male and female. When the eggs are laid, the female, in the space of fifteen days, not including the three days during which she is employed in laying, continues to hatch, relieved at intervals by the male. From three or four o'clock in the evening, till nine the next day, the female continues to sit; she is then relieved by the male, who takes his place from ten till three, while his mate is feeding abroad. In this manner they sit alternately till the young come out. Kept with ordinary care, a pair will give to the breeder nine pairs or so in a year, and will continue to do this for four years.

With regard to the best breeds of the common domesticated pigeon, it is difficult to give any useful instructions. They have been cultivated to a great extent, and many distinct varieties have been formed, but the differences rest chiefly in colours, and the special value of each lies in the taste of the *fancier*. The leading varieties of fancy-pigeons are known by the names of the English Pouter, the Dutch Cropper, the Horseman, the Unleper, the Dragoon, the Tumbler, the Leghorn and Spanish Runt, the Trumpeter, the Nun, the Fan-tail, and the Capuchin. The peculiarities of some of these breeds are very odd. The English pouter, depicted in the frontispiece, possesses the remarkable property of blowing out its breast or crop to such an extent, that it rises to a level with its beak, and the bird appears to look over the top of an inflated bladder.

Carrier-pigeons.—Pigeons have been put to the remarkable purpose of acting as carriers of letters or other light objects. A particular species, larger than common, is trained for the purpose, and in some countries the rearing of them forms a lucrative employment. The instinct which has rendered the carrier-pigeon so serviceable, is the strong desire manifested by all pigeons to return to the place of their ordinary residence; and man has adopted various precautionary measures in order to make its return on particular occasions more certain. A male and female are usually kept together, and treated well; and one of these, when taken elsewhere, is supposed to have the greater inducement to come back. It is even considered necessary by some that the bird should have left eggs in the process of incubation, or unfledged young ones, at home, in order to make the return certain; but probably these are superfluous precautions. It is obvious that the carrier-pigeon can only be put to use in conformity with some contemplated plan, for which the proper preparations have been made. It must have been taken from a place to which it is wished that it should return, and it must, at the moment when its services are wanted, be temporarily at the place from which the intelligence is to be conveyed. It is usually taken to that place hoodwinked, or in a covered basket: the instinct by which it finds its way back upon its own wings must of course be independent of all knowledge of the intermediate localities. When the moment for employing it has arrived, the individual requiring its services writes a small billet upon thin paper, which is placed lengthwise under the wing, and fastened by a pin to one of the feathers, with some precautions to prevent the pin from pricking, and the paper from filling with air. On being released, the carrier ascends to a great height, takes one or two turns in the air, and then commences its forward career, at the rate of about forty miles an hour.

CAGE-BIRDS.

The birds usually domesticated in cages in Britain are canaries, siskins, goldfinches, bullfinches, larks, linnets, thrushes, blackbirds, starlings, and parrots. The only means by which these or any other species of birds can be reared and preserved in a healthy condition, is to accommodate each as far as possible with the food, space for exercise, and other conveniences which the animal would enjoy in a state of nature. The most difficult thing to afford is space: where a room or aviary can be fitted up with all requisite accommodations—perches to resemble trees and branches, grass, moss, and other plants, patches of gravel or sand, secluded places for nests, a trough of clear water, &c.—the birds will thrive, breed, and be cheerful; but such accommodations can rarely be afforded, unless in the mansions of the great; and the aviary, for the most part, is only a tiny cage, more or less ornamental, formed of wood and wires.

Placed in this state of confinement, no birds can possibly exist unless great care is bestowed in furnishing them with food and fresh water daily, keeping their habitation very clean, and placing them in a cheerful situation in a parlour, where they can enjoy the light.

The food of cage-birds is very various. 1. Canaries, goldfinches, and siskins, live only on seeds; 2. quails, larks, chaffinches, and bullfinches, feed on both seeds and insects; 3. nightingales, redbreasts, thrushes, and blackbirds, take berries and insects. Referring to these classes of birds, Bechstein observes: 'Experience teaches me that a mixture of crushed canary, hemp,

and rape seed, is the favourite food of canaries; goldfinches and siskins prefer poppy-seed, and sometimes a little crushed hemp-seed; linnets and bullfinches like the rape-seed alone. It is better to soak it for the young chaffinches, bullfinches, and others: in order to do this, as much rape-seed as is wanted should be put into a jar, covered with water, and placed in a moderate heat, in winter near the fire, in summer in the sun. If this is done in the morning, after feeding the birds, the soaked seed will do for the next morning. All of them ought to have green food besides, as chickweed, cabbage-leaves, lettuce, endive, and water-cresses. Sand should be put in the bottom of the cages, as it seems necessary for digestion.

'Amongst those of the second class, the quails like cheese and the crumbs of bread; the lark, barley-meal, with cabbage, chopped cress, poppy-seed mixed with bread-crumbs, and in winter, oats; the chaffinches, rape-seed, and sometimes, in summer, a little crushed hemp-seed. Too much hemp-seed, however, is hurtful to birds, and should only be given as a delicacy now and then, for when they eat too much of it they become asthmatic, blind, and generally die of consumption. Yellow-hammers like the same food as the larks, without the vegetables; the tits like hemp-seed, pine-seed, bacon, meat, suet, bread, walnuts, almonds, and filberts.' The same author proceeds to describe two kinds of paste, simple and cheap, and which may be termed a universal food for birds.

'To make the first paste, take a white loaf which is well baked and stale, put it into fresh water, and leave it there until quite soaked through, then squeeze out the water, and pour boiled milk over the loaf, adding about two-thirds of barley-meal with the bran well sifted out, or, what is still better, wheat-meal; but as this is dearer, it may be done without.

'For the second paste, grate a carrot very nicely (this root may be kept a whole year if buried in sand), then soak a small white loaf in fresh water, press the water out, and put it and the grated carrot into an earthen pan, add two handfuls of barley or wheat meal, and mix the whole well together with a pestle.

'These pastes should be made fresh every morning, as they soon become sour, particularly the first, and consequently hurtful. For this purpose, I have a feeding-trough, round which there is room enough for half my birds. It is better to have it made of earthenware, stone, or delf ware, rather than of wood, as being more easily cleaned, and not so likely to cause the food to become stale.'

Canaries are the chief pets of the parlour, and the method of treating them requires to be given at some length. Being originally from a warm climate, they are tender, and must be kept in rooms of an agreeable temperature; if exposed to cold either in rooms or the open air, they pine and die. In dry weather in summer, their cage should be hung in the open air, or at least in the sunshine. If the apartment is kept too hot, they will moult at an improper season, and this must be avoided. Only one male should be allowed in a cage. Females for breeding are the better for having a large cage, as it affords them space for exercise. The greatest care must be taken to clean the cage, of whatever dimensions, and to scatter a little fine sand on the bottom of it. Each should be provided with three cross-sticks as perches; a small glass-trough for water fixed outside, at the extremity of one of the sticks. The water must be changed daily, or even more frequently.

Some persons, from mistaken kindness, offer pieces of rich cake and other inappropriate food to canaries, and the little creatures being fond of these things, they do themselves a great injury by eating of them.

The breeding of canaries requires additional accommodations. The breeder must have a large cage, into which the pair of birds is put about the middle of April. At the upper part of the cage, at one end, boxes for the nests are placed, with holes to go out and in by; and in the centre of the cage, near a perch, a net-work bag is hung filled with cotton, wool, moss, hair, and other soft materials, for the birds to use for their nests. The female only builds; and in about ten days after pairing, she lays the first egg. She ordinarily lays six eggs—one every day; but each egg is to be taken away as laid, leaving an ivory one only; and when she has done laying, replace all the six. The period of incubation is thirteen days. When the young are hatched, finely minced egg and bread should be placed near the feeding-trough, to enable the parents to carry suitable food to their young. Canaries will mate with siskins, linnets, several of the finches, and other allied birds, producing in many instances highly esteemed mules.

The system of treatment now described is also well adapted for the siskin, of which there are several varieties, as the black, white, and speckled.

The *sky-lark* requires a roomy cage, at least eighteen inches long, nine wide, and fifteen high: the bottom should have a drawer, in which enough of river-sand should be kept for this scratching-bird to be able to roll and dust itself conveniently. It is also a good plan to have in a corner a little square of fresh turf, which is as beneficial as it is agreeable. The top of the cage must be of linen, since, from its tendency to rise for flight, it would run the risk of wounding its head against a covering of wood or iron-wire, especially before it is well tamed. The vessels for food and drink must be outside, or, which I prefer, a drawer for the food may be introduced in the side of the cage: sticks are not necessary, as the lark does not perch.

The *starling*, if well treated, soon becomes exceedingly familiar, and may be taught to whistle various airs, and pronounce words and short sentences with accuracy. For these ends, no cutting or slitting of the tongue is requisite—an operation as stupid and unnecessary as it is cruel and barbarous.

Parrots.—Under this head may be classed a number of beaked birds of similar character, as parrots, perroquets, cockatoos, and macaws, all possessing beautiful plumage of green, crimson, yellow, or grayish tints. They are chiefly from South America, and require the warmth of a dwelling-house to keep them alive in this country. All possess harsh voices, and would on that account be considered a positive nuisance by most persons, except for the oddity of their being able to repeat certain words; but this is a quality possessed by some in greater perfection than others. All the species of these birds may be treated much in the same manner. They are allowed a large cage, formed of strong wires, with thick round bars to perch upon, and a ring at top to swing from by their hooked beak. All the parts must be of tin, for they would soon peck wood to pieces. In Zoological Gardens, they are usually seen perched on a cross-bar of tin at the top of a staff, but chained by the leg to prevent their escape; but this method is not so favourable for their climbing, swinging, and grotesque manœuvres as a large roomy cage.

The food offered to parrots, macaws, &c., is chiefly bread steeped in milk, nuts, or any other simple article. Care must be taken never to give them anything containing salt or pepper.

The cockatoo is generally esteemed as of milder temper than the parrot. For ornamental pets, perroquets—many of which are not much larger than the common house-sparrow—are now very generally preferred; and though not quite so showy in plumage as the macaws, lories, and cockatoos, yet their tints are often extremely beautiful, and they never become offensive by screaming, which is too often the case with their larger congeners.

THE HONEY-BEE.

THE subject of Bees, which is equally extensive and interesting, has for many ages attracted the attention of mankind. The Sacred Writings, the most ancient of which we have any knowledge, shew in numerous places how strongly the fathers of the Jewish people had been impressed by the peculiarities in the natural history of the Bee; and we know that Aristotle and other philosophers of old Greece deemed the subject worthy of years of patient investigation. Virgil also, and many other Roman authors, dwelt on it with enthusiasm in their writings; while, in much later times, Swammerdam and other distinguished cultivators of science have pursued the same track with undiminished ardour. The most zealous of these inquirers was Francis Huber (born at Geneva 1750, died 1831), who, though labouring under the deprivation of sight, by the aid of his wife formed a most valuable collection of observations on the habits of bees, and to whose work—as yet the best of its kind—we shall have frequent occasion to refer. Societies have also been formed for the sole purpose of investigating this portion of natural history. A mere summary of the interesting essays, therefore, which this insect, so universally appreciated, has called forth, would occupy a very large space. On the present occasion, an attempt can only be made to cull from the most approved sources such details as may form a complete history of the Honey-bee, though at the same time it must necessarily be a concise one, along with directions for the practical management of this most useful insect.

Bees are arranged by zoologists into the family of the *Apidæ* (*apis*, a bee), in the order *Hymenoptera* (having four unequal membranaceous wings) of the Insect class. The Social Bees form the principal division of the family, their type being the *Apis mellifica*, the Honey-making, or, in common phrase, the Honey-bee. It is so called, not from an exclusive peculiarity, but because it is the species which has long yielded to man the rich product indicated in its name. As the observations to follow will have reference to the Honey-bee, it may simply be mentioned that the description of this species involves the leading features in the natural history of its less important congeners, the Wild or Humble Bees. (See ZOOLOGY.)

ANATOMY AND PHYSIOLOGY.

Of the family of the Social Bees, two species seem to exist in Europe, the one found in the north, and the other in the south; but, making allowance for a slight deepening of tint from brown to red in the rings of the body in the case of the more southerly insect, the description of the common hive-bee of Britain will apply to the other in all important respects. A hive of honey or garden bees contains three ranks or sexes of inhabitants, the external characters of which differ considerably, while their uses and functions in the community are most obviously distinct. The most important, and by far the most numerous rank, is that of the *workers*, or working-bees, formerly regarded as neuters in respect of sex, but now more properly considered as undeveloped females. The second rank is composed of the males of the hive, termed the *drones*. There is usually but one perfect member of the third rank present at a time in a hive, and this is the *queen*, or mother-bee, the sole female of the community.

Workers.

The working honey-bee has a body about half an inch in length, blackish-brown in hue, and covered with close-set hairs, which are feather-shaped, and assist the creature materially in collecting the farina of flowers. The *head*, which is a flattened triangle in shape, is attached to the chest by a thin ligament; and the chest or *thorax*, which is of a spherical form, is united in a similar way to the *abdomen* (see No. 9). The abdomen is divided into six scaly rings, which shorten the body by slipping over one another to a certain extent. These three external divisions of the insect's body have all of them appendages of peculiar interest and utility. The head is provided with a double visual apparatus. In front are placed two *eyes*, consisting each of numerous hexagonal plates, studded with hairs, to ward off the dust or pollen of flowers; and three small eyes are also to be found on the very top of the head, intended, doubtless, both to heighten the general sense of seeing, which the creature so peculiarly requires, and to give a defensive vision upwards from the cups of flowers. The *antennæ*, however, which are two slender horns springing from betwixt the front eyes, and curving outwards from each side, most probably fulfil many of the purposes of vision in the dark interior of the hive. These instruments have each of them twelve articulations, and terminate in a knob, gifted with the most delicate sensitiveness. By the flexibility of the antennæ, the bee is enabled to feel and grasp any object in its way; and there can be little doubt that it is chiefly by means of these it builds its combs, feeds the young, fills the honey-cells, and performs the other operations of the hive. Bees also use these appendages for the recognition of one another.

The mouth of the bee is a very complex structure, and one wonderfully fitted for its duties. Its most important parts are the *mandibles*, the *tongue*, the *proboscis*, and *labial feelers*. The mandibles are merely the two sides of the upper jaw, split vertically, and movable to such a degree as to enable the insect to break down food betwixt them, to manipulate wax, and use them otherwise as serviceable tools. They are furnished with teeth at their ends, two in number. The tongue of the bee is extremely small, and indeed is scarcely admitted by some naturalists to exist at all, the proboscis being often signified by that name. Many of the usual functions of such an instrument are indeed performed by the proboscis, a long slender projection, composed of about forty cartilaginous rings, fringed with fine hairs. From the base of this, on each side, rise the labial feelers, instruments also fringed or feathered interiorly; and outside of these are the lower jaws, similarly provided with hairs. When the feelers and jaws close in on the proboscis, they form a sheath or defence to it. Naturalists used to term the proboscis a tube; but they now know that it acts by rolling about and lapping up, by means of the fringes around it, everything to which it is applied. The gathered material is then conveyed into the gullet at its base, whence it passes into the internal organs. Thus we find the mandibles of the upper jaw ready to break and prepare the food for the sweeping-up apparatus of the lower parts. While perfect in action in an expanded state, the whole, moreover, can be so folded or coiled together, as to form one strong well-protected instrument.

To the trunk or thorax of the bee exteriorly are attached the muscles of the wings and legs. The wings consist of two pair of unequal size, which are hooked to one another, in order to act in concord and steady the movements in flying. The bee has three pair of legs, of which the anterior pair are the shortest, and the posterior the longest. All of them are formed upon

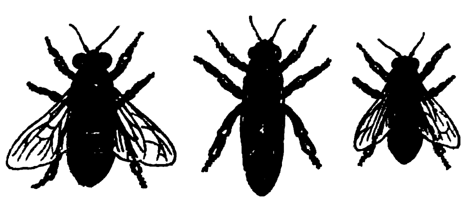
the same principle as the limbs of man, having articulations for the thigh, leg, and foot, with some minor joints in the latter part. The hind-legs are marked by a special and beautiful provision: this is a cup-like cavity on the *tibia* or fore-leg, intended for the important purpose of receiving the kneaded pollen which the bee collects in its wanderings. The legs are all thickly studded with hairs, and more particularly the cavity mentioned, in which the materials require to be retained securely. Another provision of the bee's limbs consists in a pair of hooks attached to each foot, by means of which the animal suspends itself from the roof of the hive or any similar position. Beneath or behind the wings, the *spiracles* or air-openings are found, which admit air for the purpose of permeating the chest and probably the whole body, for the oxygenation of the circulating system. Huber completely proved both that respiration is essentially necessary to bees, and that the spiracles are the instruments by which it is effected. He found that they die in an exhausted receiver, and become asphyxiated when shut up in numbers in close bottles. They perish in water only if the spiracles are under the surface; and the use of these apertures is then made apparent by the bubbles which escape from them under water. As will be shewn, also, bees carefully ventilate their hives. Therefore, though no blood has been detected in bees or other insects, these tiny spiracles are of no slight consequence in the physical economy of the insect, oxygen being apparently not less necessary to the vitality of its circulating fluids than to those of warm-blooded animals.

Besides these appendages and contents of the chest, that region is traversed by the *œsophagus* or gullet, on its way to the digestive and other organs situated in the abdomen. These organs consist of the *honey-bag*, the *stomach*, the *wax-pockets*, and the *intestines*, with the *venom-bag* and *sting*. The honey-bag, sometimes called the first stomach, though digestion never takes place there, is an enlargement of the gullet into a pea-sized bag, pointed in front, with two pouches behind. In this receptacle is lodged the fluid or saccharine portion of the bee's gatherings, and by the muscularity of the coats, it can be regurgitated to fill the honey-cells of the hive. A short passage leads to the second or true stomach, which receives the food for the nourishment of the bee, and also the saccharine matter from which the wax is secreted. The small intestines receive the digested food from the stomach, and from them it appears to be absorbed for the purposes of nutrition. Wax, it was once thought, was pollen elaborated in the stomach and ejected by the mouth; but it is entirely derived, it is now known, from the honey or saccharine matter consumed by the insect; and John Hunter discovered two small pouches in the lower part of the abdomen, from vessels on the surface of which it is secreted. After accumulating for a time in these pouches, scales of it appear externally below one or other of the four medial rings of the abdomen, and are withdrawn by the bee itself or those around it. Close to the stomach is found the last important organ of the abdomen, the sting. Much beautiful mechanism is observed on a microscopic examination of this weapon, so powerful in comparison to its bulk. It consists of two long darts, adhering longitudinally, and strongly protected by one principal sheath. This sheath is supposed to be first thrust out in stinging; and its power to pierce may be conjectured from the fact that, when viewed through a glass which magnifies a fine needle-point to the breadth of a quarter of an inch, the extremity of the sheath ends so finely as to be invisible. The sheath once inserted, then the two still finer darts follow, and make a further puncture. The use of this is to receive the poison, which is conducted to the end of the sheath in a groove; and in order that the conjoined darts may not be withdrawn too soon for this purpose, they have each nine or ten barbs at the point to retain them. When the weapon is withdrawn, the poison is thus left with a cavity to enter, causing a deeper festering. The insect ejects the poison by means of a muscle encircling the bag at the base of the sting, in which bag the venom is secreted. The chemical composition of the poison has not been discovered, though it has so far the nature of an acid as to redden the vegetable blues. Altogether, Paley, in his *Natural Theology*, is fully justified in pointing to the defensive weapon of the bee as a wondrous union of mechanical and chemical perfection.

The manner in which the bee collects the food which forms the various secretions alluded to, is worthy of note. The hairs with which its body and feet are covered, are the main instruments used for this end. By means of the hairs on the feet, the insect usually begins its collection of the pollen in the corolla which it has entered, and after kneading the dust into balls, finally places it in the baskets of the hind-legs. But the creature is not content with the product of this process. Rolling its body round and round, it brushes off the pollen still more cleanly, gathers it into two heaps with its active brushes, and loads its baskets to the brim. Even afterwards, they sometimes fly home like dusty millers, and brush their jackets when unloaded. The pollen is understood to be brought home by the working-bees more peculiarly as food for the young. The fluid secretions contained in the nectaries of flowers, and honey-dew, which is a deposition of certain aphides on plants, serve as other natural varieties of the bee's food. The insect is also at certain periods a liberal drinker of water.

The senses of bees have been in part touched upon already. The means of *vision* bestowed on them, it was mentioned, consist of the many-lensed eyes in front, and the supplementary organ above. Inquirers have been staggered by the seeming contradictions connected with the vision of the bee. After collecting its store of food, its first movement is to rise aloft in the air, and look for the site of its home. Having determined this in an instant, however distant the hive may be, it goes for the point with the directness of a cannon-ball, and usually alights at its own door, though the whole country be crowded with hives. Yet if the hive, or its door, has been shifted to a slight extent, the insect seems confused, and cannot find its way. The conclusion from this is, that the eyes of the bee have a lengthened focus, suiting them for the main purposes of its existence. But the consequent inability to determine accurately on short distances has been compensated to the creature by the antennæ, which then become a highly serviceable resource. The sense of *taste* in bees has been the subject of much argumentation. Huber was of opinion that it was the most imperfect of their senses, and they have been observed to resort to putrid marshes for water, even when they were not restricted in their choice. Xenophon found his men seriously injured by taking honey produced by bees which had fed on deleterious plants. But, on the other hand, it has been noticed that they reject many substances, and prefer others, when a choice is allowed them; and it has been conjectured that they go to marshes purposely for the salt in their waters. Moreover, what renders the honey deleterious to man, may not be hurtful to bees. Honey formed from a particular flower in the Jerseys, was found unfit for use from its intoxicating qualities; yet the bees throve wonderfully upon it all the while. Their taste in selecting the richest flowers is likewise unquestionable. No doubt the sense of *smell* comes into operation on these occasions, as well as the sense of taste. Betwixt the influence and effects of the two, indeed, it is scarcely possible to discriminate. Even in the case of the human being, it is an established fact, that the powers commonly ascribed to the sense of taste are to a remarkable degree dependent on the sense of smell. If the eyes be bandaged, and the apertures of the nose well shut up, the most experienced

judge will be at a loss to determine between any two kinds of ardent spirits, or other pungent substances. The most nauseous medicines, also, much as they may usually seem to affect the taste, will be found almost insipid if the site of the sense of smell be closed up while they are swallowed. In bees, the site of the two senses seems to be almost one and the same. Many experiments of Huber seem to prove that the sense of smell lies in the mouth, and that it is very acute. He found that they hate the odour of turpentine; yet on plugging up the mouth, they shewed no disgust when placed beside that liquid. He concealed honey at considerable distances, and they in a very short time detected the hidden treasure. The acuteness of their sense of smell, in truth, is sufficiently proved by their admirable skill in tracking out, over hill and dale, the most fragrant flower-parterres and beds of mountain-heath. The sense of *hearing* has been denied to bees by many observers, while others describe the antennæ as their organs of hearing. The probabilities are in favour of the latter position. Noise, produced by the wings, and varied to suit particular purposes, is well known to be used as a mean of intercommunication; and Huber, though doubtful about the faculty, avers that by a particular sound, emitted from the mouth apparently, the queen will render the whole hive silent and motionless in one instant. A certain sound, too, heard in the hive before swarming, is always followed by definite consequences. Such facts as these go far to establish the possession of hearing by bees; as signals by sound, made when the eyes could not detect the movement attending their production, would otherwise be valueless. The antennæ have been mentioned as possessed, if not of hearing, at least of a delicate sense of *touch*. Huber points out a moonlight night as the best time for observing the uses of the antennæ in this respect. The bees, guarding against the intrusion of moths, have not light enough to see fully, and they circumambulate their door with the antennæ stretched right before them. The instant a moth is felt, it is destroyed. When the queen of a hive is lost, the antennæ form a curious means of spreading intelligence. Bee after bee protrudes its antennæ, and crossing them with those of his next neighbour, disseminates in this way the sad news over the hive. Besides the antennæ, the feelers have been shewn by experiment to possess a considerable degree of sensibility, and to serve in part as organs of touch.



Drone. Queen. Worker.

Such are the anatomical and physiological characteristics of the common or working bee. The duties of this order include almost the whole business of the bee community, as will be shewn afterwards in detail. Hives differ greatly, of course, in the number of their inmates, taking them even at the same season. Some contain but a few thousands; others from twenty to thirty, forty, and even fifty thousand. Of these the drones compose but a thirtieth part, or little more; all the rest, with the exception of the queen, are workers.

Drones or Males.

The drones differ considerably in outward appearance from the workers: they are bulkier and flatter in body, with a round head, a shorter proboscis, and antennæ with an additional articulation; they have no basket-cavity on their hind-legs, and their abdomen contains the means of secreting neither honey, wax, nor poison, while the reproductive organs are there found instead. They are called drones from the peculiarly loud noise which they make with their wings. It has been already stated that the drones are the males of the hive. They live but for the reproduction of the race, and when the object of their existence is accomplished, they are doomed to die. The workers, who have their own winter food and that of the coming young to provide, instinctively pass sentence of death at the fitting time; despatch the defenceless males with their stings, and cast them forth from the hives, in which, from their size and voracity, their presence has now become a positive evil. With these exceptions, the description given of the worker-bee applies also to the drone.

Queen-bees.

The queen-bee is of larger size than either the drone or the worker: she has an elongated body, blackish above, and tinted with yellow inferiorly, while the presence of two ovaries or egg-receptacles in the abdomen demonstrates her sex. She has also a sting, considerably bent. The Germans call the queen the *mother-bee;* and this is the most appropriate name, since her functions are those of a parent rather than a potentate. Her sole province is to lay the eggs, from which issue those annual multitudes that perpetuate the race in new communities. The progress of all kinds of bees, from the larva state to maturity, will fall to be described in an ensuing section; but it may in the meantime be observed, that the queen usually commences laying eggs on the fifth day after she has assumed the perfect state, and often continues without intermission from early spring to the end of September, laying in the warmest season about two hundred eggs a day. Such are the distinguishing characteristics and functions of the mother-bee.

We propose now to give an account of the natural and regular operations of a colony of bees, from the moment of their introduction to an unfurnished habitation, to the establishment of a perfect hive.

NATURAL ECONOMY OF THE HIVE.

The breeding of young bees commences in February, and a hive, however thinned by the previous winter, becomes, under ordinarily favourable circumstances, crowded to excess in midsummer. Besides the developed bees, it abounds in eggs and young ones not matured. That fine instinct which, in the case of bees, occasionally prompts to acts almost above the power of reason, relieves this crowded state of things. The queen-bee, the proper mother of at least the great body of the hive, resolves upon departure with a swarm. The phenomena attending that departure will be noticed under a separate section; in the meantime, let it be supposed that the queen has led off a colony, and that, by the care of the owner of the bees, the swarm is lodged in a new and empty hive.

The first object of the community is to clean out their new lodging thoroughly, if they find this not done beforehand. The next great object is to block up all the chinks of the hive, smooth its projecting parts, and lay a stable foundation for the future works of the interior. Besides the wax which they use so extensively in their architecture, bees also employ, particularly at first, a remarkable substance called *propolis*, from the Greek words *pro* and *polis* (before the city), as indicating its use on the superficial parts of the hive. Propolis is a grayish-brown resin, of an aromatic odour, and better fitted by its tenacity for cementing than wax. Huber first shewed distinctly that the bees gather this from the poplar, alder, birch, and willow trees, but more especially from the first of these trees. That ingenious naturalist, suspecting Reaumur to be wrong in referring the propolis to the pine, placed near his hives some wild poplar branches, which the bees soon discovered, and flocked to in great

numbers. In the heat of the day, when the viscous matter is ductile, it is thus carried off by the insect. A small thready portion is detached, kneaded with the mandibles, and then, by means of the fore-feet, placed in the basket of the hind-legs, a smart pat or two being given to secure it there. Another portion, similarly kneaded to make it portable, and a little drier, is basketed in the same way, till as much is procured as the insect can carry. Sometimes the patient creature will spend half an hour in the mere kneading of a portion of propolis; and occasionally other bees will come behind and rob the little labourer of its whole load, for a succession of times, without eliciting the slightest symptom of impatience. When a bee reaches the hive with its load, the propolis adheres so firmly, that the insect has to present its limbs to the workers in the hive, who detach it, and immediately use it, while yet ductile, to fill all the crevices of the hive, and smooth the projecting parts, so as to prevent hurts being received in the dark. Another remarkable use is made of the propolis. From the hour of their entrance into the hive, bees are liable to the intrusion of other creatures. A fly they can soon remove, but what are they to do with a snail? They can sting it to death, to be sure, in an instant, but their puny strength is totally insufficient to remove the carcass. In this dilemma, they completely obviate the disagreeable effects of the presence of a large putrefying body, by covering it with propolis, which hardens over the mass, and gives a pleasant aroma in place of a fetid odour. With the propolis, moreover, they often narrow the entrance to the hive, forming a secure barrier, when they have reason to dread the intrusion of the death's-head moth, their great enemy in some countries.

In the meantime, while some workers are using the propolis for the purposes first stated, others are commencing the preparation of the cells or combs. The propolis is employed to attach these to the edges of the hive, but wax is the component material of the cells themselves. We shall find, in noticing the after-arrangements of the completed hive, that the working-bees are naturally divided into two great classes; but at the outset of their labours, when the cells are being constructed, they form *three* sections, each of which pursues its allotted toil with admirable order and regularity. One section produces the material for the combs, and forms it roughly into cells; the second division follows the first, examines and adjusts the angles, removes all the superfluous wax, and perfects the work; while the third band passes continually out and in, seeking and bringing provisions, chiefly pollen, for the second section, which never quits the hive. The first class fly abroad at intervals, it being necessary that they should have rich saccharine food for the secretion of the wax. As the secretion goes on best in a state of repose, bands of the wax-producers, after feeding fully, suspend themselves in clusters from the roof, each hanging from the hind-legs of the one above, till the wax-scales are formed, and they are prepared to take up the work. This clustering occurs on the very entrance of a swarm into a hive, when a seeming inactivity of several hours takes place, till the production of wax is set agoing. It will be seen that the second section, the architects proper, have the most unremitting toil to perform. They never quit it when once begun, excepting to turn to the little waiters of the third section, and indicate their hunger by holding out their trunk, when the caterer either spirts out a drop or two of honey, or furnishes pollen from the stores brought in.

Cells.

But if the labour of the architect class be severe, their work, when complete, is a marvel of instinctive ingenuity. Bees always begin their work, in ordinary circumstances, at the ceiling, suspending their structures from it. Their combs, or clusters of cells, are arranged in vertical and parallel plates, with a space of about half an inch betwixt contiguous pairs; and each comb is nearly an inch in thickness. At the outset, when one wax-making bee leaves the suspended cluster alluded to, and lays the foundation of a cell, others follow in rapid succession, not only adding their wax to that of the first, but soon commencing new combs, one on each side; and so the work goes on, in most cases, until the whole roof is covered with foundations. The architects proper, also, are meanwhile at their finishing-work. They have, says Reaumur, to solve this difficult geometrical problem: 'A quantity of wax being given, to form of it similar and equal cells of a determinate capacity, but of the largest size in proportion to the matter employed, and disposed in such a manner as to occupy the least possible space in the hive.' Wonderful to reflect upon, this problem is solved by bees in all its conditions, in their construction of hexagonal or *six-sided* cells. The square and the equilateral triangle are the only other two figures which could make the cells all equal and similar without interstices. But cells of these figures would have either consumed more material or have been weaker; and they would also have occupied more space, being less adapted to the form of the bee. In short, the hexagonal form combines all the requisites of economy and capacity. Another wonderful arrangement is seen in the construction of the bottoms of the cells. Each of these is composed of three rhombs, or plates of wax in the shape of card-diamonds, disposed in such a manner as to form a hollow pyramid, the apex of which forms the angles of the bases of three cells on the opposite side, giving to each of them one of the three diamond-shaped plates which is required to form their bases. Now, the three rhombs, composing each cell-bottom, have the two obtuse angles each of 110 degrees, and, consequently, each of the two acute angles of 70 degrees. Koenig, on being desired by Reaumur to calculate the exact angle which would give the greatest economy of wax in a cell of such capacity, found that the angle should be 109 degrees 26 minutes, or 110 degrees nearly. Other geometricians have arrived at similar conclusions. The problem is one of great difficulty, yet the bee practically solves it at once, under the guidance of the Great Geometrician who made both the bee and the law on which it proceeds. Attempts have been made to ascribe the form of the cells to the peculiar shape of the head of the bee, and the instruments which it employs; but all such explanations have been found liable to insuperable objections.

The cells of the bee are extremely delicate, two or three plates or sides being of the consistence only of a common leaf of paper. They are made strong, however, by mutual support and other means. Besides a sort of froth which the insect mixes with the wax, the cells, at first of a dull white, soon appear yellow on the interior, the change arising from the plastering over them of a compound varnish of wax and propolis. Each cell is soldered, too, at its mouth by a similar compound of a reddish colour, having in it more propolis; and threads of the same substance are laid around the walls, to bind and strengthen them. It is now to be observed that all cells are not alike. They have four different uses in the economy of the hive, and are constructed variously to suit these. One set of cells is for holding the eggs or embryos of worker-bees; a second for those of males or drones; a third for those of young queens, hence called royal cells; and a fourth set are for the reception of honey and pollen. The first are generally about five lines in depth (or less than half an inch), and two lines and two-fifths in diameter. The cells of the young males are much less numerous, and measure from six to seven lines in depth, by three and a half in diameter. It is worthy of note, that in passing from the construction of worker-cells to those of drones, in the same comb, the architects do not alter the size at once, but gradually, thus disordering in the slightest possible degree the delicate arrangement of the bases of the cells. In shifting from larger to smaller, the same rule is observed. A small

number only of royal cells, about ten or twelve, are constructed on ordinary occasions. They are about an inch in depth, and nearly one-third of an inch in width, with walls about an eighth of an inch in thickness. After the breeding season is over, the cells both of worker and male bees are used for holding honey. Those made purposely for that end are chiefly marked by a greater divergence from the horizontal plane, that the honey may be better secured; and it is curious to observe that, in a very warm season, these wise insects give the floor a still greater dip from the mouth inwards. As the store enlarges, they seal up the mouth with a ring of wax, to which they gradually add concentric layers till the cell is filled, when they close it altogether—reserving its treasure for use during winter and spring. Pollen, as brood food, is kept in cells of considerable size.

Laying of Eggs.

A very short time elapses ere a great number of cells are constructed; for, in the height of the honey season, a good swarm has been known to build *four thousand* in a day. The queen-mother very soon begins the task of laying eggs. A thousand conjectures have been hazarded as to the mode in which the fecundation of the female bee takes place. No observer has yet been able to discover any contact with the drones in the hive. It was supposed by Swammerdam that a certain aura or odour from the males was all that was necessary to render the eggs of the queen productive; while M. Debrau imagined that the eggs, as in the case of frogs and fishes, were fecundated by a fluid from the drone after being laid. M. Hattorf thought, again, that the queen was fecundated by herself alone. All these opinions Huber refuted in a satisfactory manner, by separations and confinements of the insects in various ways. He at length came to the belief, founded on experiments which appear almost decisive of the question, that the female bee never becomes fruitful in the hive, but requires to go abroad for that purpose; and it has been also thought probable that the fecundation takes place by contact in the air, as is known to occur in the case of winged ants. The number of drones in a hive has been thought a most unintelligible circumstance. Huber's views explain the matter fully. It is essential that they should be numerous, that the female may have a chance of meeting them abroad; and it is to be observed that she always quits the hive at the hour when the drones leave it, or immediately afterwards. One intercourse is sufficient, according to Huber's experiments, to render the female bee productive for at least two seasons; and if the intercourse takes place at the end of the year, the consequent laying of eggs may be deferred till the ensuing spring. The cold weather has a powerful influence in this respect.

M. Huber discovered that the queen begins to lay eggs forty-six hours after returning from the flight during which fecundation takes place. For the space of eleven months, under ordinary circumstances, a queen, at her first laying, produces the eggs of worker-bees alone. At the end of the space mentioned, a considerable laying of the eggs of drones commences; and soon after the appearance of these, the workers of the hive, with a strange instinct, begin to prepare royal cells for the queen-eggs that are certain to follow. Altogether, the fruitfulness of the female bee is amazing, from 100 to 200 eggs a day being the usual amount of her produce: 100,000 is said to be no very uncommon number of young for her to give origin to in a single season. A swarm consisting of 2000 or 3000 in the beginning of the year, will throw off in June swarms amounting to 40,000 or 50,000; in many cases the first swarm, and in some the cast or second swarm, throw off colonies of 10,000 or 12,000; and yet the original stock is left augmented to the number of 18,000 or 20,000. Occasionally, an early and numerous first swarm casts even twice.

Transformation of Worker-bees.

A fertilised queen is so impatient to begin her laying of worker-eggs, that in a new hive, she only waits till a few inches of comb are erected. Before depositing the egg, she carefully examines the cell, and, if satisfied, turns and drops into it from the oviduct, an egg of an oval shape and bluish-white tint. Here the egg remains for three days attached by a viscous fluid to the corner of the cell; and, on the fourth, the thin outer shell of the egg bursts, exposing a small lively worm. Now come into play the *nurses* or nursing-bees, one of the two great sections into which Huber and others consider the labours of the hive to be divided. The other class are the *wax-workers*. Both elaborate honey, but the latter class alone make wax and form combs. Again, the nurses, whose figure may be distinguished from its being more ovoidal than the others, are those who alone take care of the young. As soon as the egg is hatched, they watch over the larva or worm with the tenderest and most incessant care, administering copious supplies of mixed pollen, honey, and water, which the nursling devours with avidity. Like other larvæ, it soon grows so as to cast its cuticle; and, five days after chipping the shell, it has become large enough to fill the cell, lying coiled up like a ring. It now ceases to eat, and the bees seal up the cell with wax. Left to itself, the larva begins the process of spinning a cocoon round its body, which it does in thirty-six hours, the material being a fine silken thread from the mouth of the spinner. In three days more it is converted into the state of *pupa* or chrysalis, when all the parts of the future bee become gradually visible through the transparent covering, assuming a darker hue day by day, and progressing to the state of the complete *imago* or insect. On the twentieth day from the deposition of the egg, the young bee begins to cut through its prison-door with its mandibles, and in half an hour makes its escape. Old writers say that the elder bees fondly caress and feed the new-comer; but later observers, of no mean authority, declare that, on the contrary, they seem to think their duty ended with the closing up of the cell, and leave the young stranger to shift for itself in the busy world upon which it has entered. One thing, however, is done by the elder bees: they instantly clean out the vacated cell, and prepare it again for eggs or honey, leaving at the same time the silk cocoon adhering to the walls.

Male Eggs—Royal Eggs.

The passage of male eggs through the larva and pupa state is attended with the very same phenomena as in the case of the eggs of workers, with the exception that the process occupies a little more time, twenty-four days in all being spent in the change. The cause of male eggs being laid, in ordinary circumstances, only after eleven months have been passed in the laying of worker-eggs, was explained by Huber. He conceived eleven months to be necessary to perfect the male eggs, and was of opinion that the arrangement of the eggs in the ovaries was such as to permit, and even compel, the retention of both male and royal eggs until they were fully matured. This idea seems to be confirmed by the ordinary course of things in the hive, but certain anomalous facts startlingly contravene it. Huber himself found, that if a young queen had not the opportunity of proving fertile within twenty days of her birth, all her after product consisted of drones, and drones alone; and, what is still more curious, he discovered that she began to produce these drones at the time when she should have laid worker-eggs—namely, within forty-six hours after fecundation. The gestation of eleven months seemed totally unnecessary in such cases of retarded fecundation. Huber confessed himself incapable of explaining this remarkable circumstance. Though we do not understand it, however, it only tends to make us marvel more and more at the perfection of order in the

bee economy. The queen-bee is never voluntarily guilty of that breach of the laws of her being, which produces such remarkable effects; and, if artificially confined till she is twenty days old, her violent agitation shews her instinctive sense of the departure from the order of nature.

The raising of workers and drones from the egg to the insect state is a simple matter in comparison with the same transition in the case of queen-bees. The royal eggs, which the queen begins to lay twenty days after she has commenced the deposition of male ones, differ in no respect from common eggs. But on the royal larva, when it breaks from its three days' confinement in the shell, the nurses bestow peculiar attentions. They watch it incessantly, and feed it with a rich *jelly*, slightly acidulous, and given in such quantities that the royal cell is usually wet with it. In five days the young majesty of the hive has grown, so as to be able to spin her web, and the bees wax up the cell. The cocoon is spun in twenty-four hours; two days and a half of inactivity follow; the larva is then transformed into a pupa, or a *nymph*, as the insect in this state is more frequently termed; and after other four or five days have passed, the royal insect is complete—the whole time occupied in the metamorphosis being about sixteen days.

Young Queens.

We have now arrived at one of the most extraordinary points in the history of the hive. The young queen, or rather queens, do not issue from their cells when perfect, like workers and drones. They are not permitted, unless the old or regnant queen has quitted the hive with a swarm, or the seat of royalty is in any other way vacated. The bees therefore close the royal cells more firmly, leaving only a small aperture to introduce food; and, acting as if aware that they may need a queen in case of swarming, they at such times will not permit the old queen to approach the cells. Her struggles to do so are often violent, and her dire hostility to her own sex leads her, if she gets near the cells, to destroy them instantly, whether in the state of full insect or nymph. The strength of this instinctive hate is even such, that a young queen no sooner leaves her own cell than she feels its stirrings.

According to Huber, there can only be a single queen in a hive. The first thought of a young queen, it has been seen, is to kill her yet undeveloped rivals. Nature has given her the chance, for, as more queen-eggs than one are seldom laid daily, one is usually the oldest. If, however, two do quit the cell at the same instant, they rush into combat with the most headlong fury. If a stranger enters a hive, its queen-regnant flies to the field without a moment's hesitation. In short, in all ordinary circumstances, two queens brought into contact, fight. But they might *both* die in the contest, and the community be left without a queen. Nature demands but one victim, and she has arranged that but one victim shall fall. Bees are only vulnerable in the belly; and Huber observed that, whenever two royal combatants were so locked together that they could mutually plant their stings in the fatal part, their instinct caused them to separate precipitately, without harm on either side. The combat only closes when one can get an advantage of position, and kill its rival with safety. Again, the worker-bees might interpose to prevent these mortal combats. On the contrary, their instinct is to prevent the queens from parting, and force on a fatal issue. Alluding to one battle, Huber says that it seemed as if 'the bees anticipated the combat in which these queens were about to engage, and were impatient to behold the issue of it, for they retained their prisoners only when they appeared to withdraw from each other; and if one less restrained seemed desirous of approaching her rival, all the bees forming the clusters gave way, to allow her full liberty for the attack; then if the queens testified a disposition to fly, they returned to enclose them.'

Another remarkable provision for insuring the existence of but one queen in a hive, is beheld in the peculiar mode in which the royal larvæ spin their cocoons. Other bees spin perfectly close cases; the queen-larvæ spin cocoons which envelop only the head, thorax, and first ring of the abdomen, leaving a part open behind. Huber thus explains this minute but important peculiarity:—'Of several royal nymphs in a hive, the first transformed attacks the rest and stings them to death. But were these nymphs enveloped in a complete cocoon, she could not accomplish it. Why? Because the silk is of so close a texture, that the sting could not penetrate, or if it did, the barbs would be retained by the meshes of the cocoon, and the queen, unable to retract it, would become the victim of her own fury. Thus, that the queen might destroy her rivals, it was necessary the last rings of the body should remain uncovered; therefore, the royal nymphs must only form imperfect cocoons. Hitherto philosophers have claimed our admiration of nature in her care of preserving and multiplying the species. But from the facts I relate, we must now admire her precautions in exposing certain individuals to a mortal hazard.'

Loss of a Queen.

If bees, by death or artificial means, are deprived of their queen, the event has a marked influence in the hive. In such a case, the following results ensue, according to Huber:—'Bees do not immediately observe the removal of their queen; their labours are uninterrupted; they watch over the young, and perform all their ordinary occupations. But in a few hours agitation ensues; all appears a scene of tumult in the hive. A singular humming is heard; the bees desert their young, and rush over the surface of the combs with a delirious impetuosity. Then they discover their queen is no longer among them. But how do they become sensible of it? How do the bees on the surface of the comb discover that the queen is not on the next comb?' It is supposed that the alarming intelligence of the loss is communicated by the strokes on the antennæ, which bees are uniformly observed to give to each other at these times. The insects then appear to seek for their lost queen, some rushing hurriedly out to make the search abroad. At the end of five hours, the commotion greatly ceases, and an instinctive recourse to the means of supplying the vacancy takes place. If they have royal larvæ, they turn their whole attention to them. If they have only the larvæ of working-bees, they immediately select two or three of them, pull down the neighbouring cells, at the cost of the lives of the young within them, and construct a royal cell around each of the selected larvæ—the consequence of which proceeding will be immediately explained. If they have no larvæ at all on the loss of their queen, still they build several royal cells, as if so far at least to supply the emergency. If a stranger queen be introduced in such a state of things, within twelve hours after the loss of their own sovereign, the new-comer is treated as an intruder, and the bees surround her so closely that she commonly dies from privation of air, suffocation being the resource of bees in such cases. If the stranger be introduced within eighteen hours, they also surround her, but leave her sooner. To shew that they possess memory, it is only necessary now to reintroduce their own queen, when they will shew every symptom of recognition and joy. But their memory is short-lived; for, if the stranger be not introduced till twenty-four hours elapse, she receives a treatment very different from that experienced at an earlier period. 'I introduced,' continues the ingenious naturalist, 'a fertile queen, eleven months old, into a glass hive. The bees were twenty-four hours deprived of their queen, and had already begun the construction of twelve royal cells. Immediately on placing this female stranger on the comb, the workers near her touched her with their

antennæ, and passing their trunks over every part of her body, they gave her honey. Then these gave place to others that treated her exactly in the same manner. All vibrated their wings at once, and ranged themselves in a circle around their sovereign. Hence resulted a kind of agitation, which gradually communicated to the workers situated on the same surface of the comb, and induced them to come and reconnoitre, in their turn, what was going on. They soon arrived; and having broke through the circle formed by the first, approached the queen, touched her with the antennæ, and gave her honey. After this little ceremony they retired, and, placing themselves behind the others, enlarged the circle. There they vibrated their wings, and buzzed without tumult or disorder, and as if experiencing some very agreeable sensation. The queen had not yet left the place where I had put her, but in a quarter of an hour she began to move. The bees, far from opposing her, opened the circle at that part to which she turned, followed her, and formed a guard around. She was oppressed with the necessity of laying, and dropped her eggs. Finally, after an abode of four hours, she began to deposit male eggs in the cells she met with.

'While these events passed on the surface of the comb where the queen stood, all was quiet on the other side. There the workers were apparently ignorant of a queen's arrival in the hive. They laboured with great activity at the royal cells, as if ignorant that they no longer stood in need of them: they watched over the royal worms, supplied them with jelly, and the like. But the queen having at length come to this side, she was received with the same respect that she had experienced from their companions on the other side of the comb. They encompassed her, gave her honey, and touched her with their antennæ; and, what proved more satisfactorily that they treated her as a mother, was their immediately desisting from work at the royal cells: they removed the worms, and devoured the food collected around them. From this moment the queen was recognised by all her people, and conducted herself in this new habitation as if it had been her native hive.'

Making of a Queen.

If one queen is not so introduced to supply the loss of another, and no royal larvæ exist, one of the most wonderful phenomena of the hive takes place. It has been stated that bees, on losing their queen, build a royal cell around an ordinary worker-bee larva, or several of them, if the larvæ are abundant. These, by peculiar feeding, are formed and developed into *queens*, thus proving that the worker-bees, commonly viewed at one time as neuters, are in reality undeveloped females. This remarkable discovery was made by Schirach. Having used smoke about a hive, he so annoyed the queen that she flew away, and the circumstance of the bees immediately building royal cells around common larvæ, when they had no royal larvæ, revealed to him the truth. Huber proved the same thing by the succeeding experiment:—'I put some pieces of comb, containing workers' eggs in the cells, of the same kind as those already hatched, into a hive deprived of the queen. The same day several cells were enlarged by the bees, and converted into royal cells, and the worms supplied with a thick bed of jelly. Five were then removed from these cells, and five common worms, which, forty-eight hours before, we had seen come from the egg, substituted for them. The bees did not seem aware of the change; they watched over the new worms the same as over those chosen by themselves; they continued enlarging the cells, and closed them at the usual time. When they had hatched on them seven days, we removed the cells, to see the queens that were to be produced. Two were excluded, almost at the same moment, of the largest size, and well formed in every respect. The term of the other cells having elapsed, and no queen appearing, we opened them. In one was a dead queen, but still a nymph; the other two were empty. The worms had spun their silk cocoons, but died before passing into their nymphine state, and presented only a dry skin. I can conceive nothing more conclusive than this experiment. It demonstrates that bees have the power of converting the worms of workers into queens, since they succeeded in procuring queens by operating on the worms which we ourselves had selected.' This curious provision seems intended to preserve the communities of bees, in any emergency, from the danger of wanting that all-important member, the queen; and it is reasonably conjectured that the evolution of a queen from a worker-larva is dependent on the effects of the royal food upon the ovarian system.

Fertile Worker-bees.

Another most remarkable fact observable in the economy of the hive was discovered by M. Riem. Common worker-bees, that naturalist proved, sometimes lay fertile eggs. It was reserved for Huber to determine this, and also to explain the cause. He in the first place found that, in a hive deprived of its queen, the eggs of drones were laid. Though he did not put faith in what had been said by some naturalists respecting the existence of *small* queens, he nevertheless satisfied himself, by directing a careful examination to be made of each individual bee in the hive, that no queen was amongst them, every one having the little basket on the hind-leg, and a straight sting. Thus convinced of the reality of Schirach's discovery, Huber, having detected several workers laying eggs, examined them, and found the ovaries partially developed. He now bethought him that the only known cause of such development is the use of the food or jelly given to the royal larvæ. Led into this train of thought, he speedily discovered that all the fruitful worker-bees are born in hives where no queen exists, and where worker-larvæ are transformed to queens; and he further found that they are always born in cells adjacent to those of these larva-queens. Continued investigations brought him to the belief, finally, 'that when bees give the *royal treatment* to certain worms, they either by accident or by a particular instinct, the principle of which is unknown to me, drop some particles of royal jelly into cells contiguous to those containing the worms destined for queens;' whence the expansion of the ovaries to a certain degree. That expansion is imperfect. As in the case of retarded fecundation in queens, the fruitful worker-bees produce nothing but drones. Ovaries, in a rudimental or undeveloped state, have been found by late observers in all working-bees.

Mutilations of Queens.

Before leaving the particular subject of queens, the remarkable effects of mutilations upon them may be mentioned. Huber cut off one antenna from a queen without any marked effects; but when he cut off both, the case was different. 'From this moment there was a great alteration in her conduct. She traversed the combs with extraordinary vivacity. Scarcely had the workers time to separate and recede before her: she dropped her eggs without taking care to deposit them in any cell. The hive not being very populous, part was without combs. Hither she seemed particularly earnest to repair, and long remained motionless. She appeared to avoid the bees; however, several workers followed her into this solitude, and treated her with the most evident respect. She seldom required honey from them; but when that occurred, she directed her trunk with an uncertain kind of feeling, sometimes on the head, and sometimes on the limbs of the workers, and if it did reach their mouths, it was by chance. At other times she returned upon the combs, then quitted them, to traverse the glass sides of the hive; and always dropped eggs during her various motions. Some-

times she appeared tormented with the desire of leaving her habitation. She rushed towards the opening, and entered the glass tube adapted there; but the external orifice being too small, after fruitless exertion, she returned. Notwithstanding these symptoms of delirium, the bees did not cease to render her the same attention as they ever pay to their queens; but this one received it with indifference. All that I describe appeared to me the consequence of amputating the antennæ.' Another similarly mutilated queen was placed beside her; they had both lost their natural combativeness. Finally, on being again left alone, the poor mutilated queen quitted the hive, unheeded, and abandoned to her fate. This evidence of the indispensable utility of the antennæ was gained, on the whole, in a manner for which even a Huber's ardour for science can scarcely form an excuse.

Massacre of the Drones.

Another of the great natural phenomena of the hive is the massacring of the drones. It was at one time asserted that the worker-bees did not use their stings against the stingless males, but merely pushed them out to die. This idea, however, resulted from the massacre being always committed at the bottom of the hive, whither the poor drones retire in clusters in July and August, as if aware of the doom impending over them. As usual, by one of his ingenious expedients, Huber discovered the truth. Six swarms were put on glass tables, beneath which the watchers placed themselves. 'This contrivance succeeded to admiration. On the 4th of July, we saw the workers actually massacre the males, in the whole six swarms, at the same hour, and with the same peculiarities. The glass table was covered with bees full of animation, which flew upon the drones as they came from the bottom of the hive; seized them by the antennæ, the limbs, and the wings, and after having dragged them about, or, so to speak, after quartering them, they killed them by repeated stings directed between the rings of the belly. The moment that this formidable weapon reached them, was the last of their existence; they stretched their wings and expired. At the same time, as if the workers did not consider them as dead, as they appeared to us, they still struck the sting so deep, that it could hardly be withdrawn; and these bees were obliged to turn round upon themselves, with a screw-like motion, before the stings could be disengaged.

'Next day, having resumed our former position, we witnessed new scenes of carnage. During three hours, the bees furiously destroyed the males. They had massacred all their own on the preceding evening, but now attacked those which, driven from the neighbouring hives, had taken refuge amongst them. We saw them also tear some remaining nymphs from the combs; they greedily sucked all the fluid from the abdomen, and then carried them away. The following days no drones remained in the hives.

'The males are never destroyed in hives deprived of queens; on the contrary, while a savage massacre prevails in other places, they there find an asylum. They are tolerated and fed, and many are seen even in the middle of January. They are also preserved in hives which, without a queen, properly so called, have some individuals of that species that lay the eggs of males, and in those whose half-fecundated queens, if I may use the expression, propagate only drones. Therefore the massacre takes place in none but hives where the queens are completely fertile, and it never begins until the season of swarming is past.'

Swarming.

Swarming usually takes place, in temperate climes, in May and June, though additional swarms, and swarms from swarms, are commonly later. In noticing the proceedings of a community from its first settlement, it was mentioned that the old queen led off the first swarm, and did so as if under alarm at the number of royal embryos, usually from twelve to twenty, which were in progress to maturity, and which the worker-bees would not allow her to approach. Other causes also operate, beyond doubt, in a certain degree. The increased heat of the hive from crowding, for example, in all likelihood influences the movement. Bees cannot do without freedom of respiration and fresh air, and it has surprised many observers to find the air usually pure, and below 80 degrees, in a hive ordinarily filled. The insects, however, have been discovered to manage this by active ventilation in their own way. A number of them are always to be seen near the inner, and sometimes the outer side of the opening of the hive, vibrating their wings with great rapidity, and sending the entering air backwards in a smart current. One band relieves another at this task. These means of ventilation, however, seem to become comparatively ineffective when the hive gets overcrowded. The heat often rises to about 100 degrees; the bees are driven to the door in clusters, while the warmth makes the hive visibly moist. At the same time, the old queen's alarm at the growth of the royal young seems to have its influence. She would fain kill them, but the worker-bees lose all respect for her, biting and beating her off with violence. The way in which they defend the royal young at swarming time, is indeed most remarkable. If, at any other season, they bring up queens from worker-larvæ, the first queen that leaves the cell is allowed to kill the rest at pleasure. But when casting colonies, the workers, as if from the sense that various swarms may be cast off, and various queens required, will not permit the old queen to touch the young, whom nature has given them the strange power of keeping alive, for better security, in their cells. Nor will they allow the first young one to whom they grant freedom to touch the rest. Huber illustrates this subject beautifully. Suppose an old queen to have left a very populous hive, as described, with a swarm—'After the departure of the colony, the remaining workers set another queen at liberty, and treat her with equal indifference as the first. They drive her from the royal cells; she also, perpetually harassed, becomes agitated, departs, and carries a new swarm along with her. In a populous hive, this scene is repeated three or four times during spring. The number of bees being then so much reduced, they are no longer capable of preserving a strict watch over the royal cells; several females are therefore enabled to leave their confinement at once; they seek each other, fight, and the queen at last victorious reigns peaceably over the republic.

'The longest intervals we have observed between the departure of each natural swarm have been from seven to nine days. This is the time that usually elapses from the period of the first colony being led out by the old queen until the next swarm is conducted by the first young queen set at liberty. The interval between the second and third is still shorter; and the fourth sometimes departs on the day after the third. In hives left to themselves, fifteen or eighteen days are usually sufficient for the throwing of the four swarms, if the weather continues favourable, as I shall explain.

'A swarm is never seen except in a fine day, or, to speak more correctly, at a time of the day when the sun shines and the air is calm. Sometimes we have observed all the precursors of swarming—disorder and agitation—but a cloud passed before the sun, and tranquillity was restored; the bees thought no more of swarming. An hour afterwards, the sun having again appeared, the tumult was renewed: it rapidly augmented, and the swarm departed.

'Bees generally seem much alarmed at the prospect of bad weather. While ranging in the fields, the passing of a cloud before the sun induces them precipitately to return. I am led to think that they are disquieted by the sudden diminution of light. For if the sky is

uniformly obscured, and there is no sudden alteration in clearness, or in the clouds dispelling, they proceed to the fields for their ordinary collections, and the first drops of a gentle shower do not make them return with much precipitation.

'I am persuaded that the necessity of a fine day for swarming is one reason that has induced nature to admit of bees protracting the captivity of their young queens in the royal cells. If the young females were at liberty to leave their cradles during those bad days, there would be a plurality of queens in the hive, consequently combats; and victims would fall. Bad weather might continue so long, that all the queens might at once have undergone their last metamorphosis, or attained their liberty. One victorious over the whole would enjoy the throne; and the hive, which should naturally produce several swarms, could give only one. Thus the multiplication of the species would have been left to the chance of rain or fine weather, instead of which, it is rendered independent of either by the wise dispositions of nature. By allowing only a single female to escape at once, a regular and successive formation of swarms is secured. This explanation appears so simple, that it is superfluous to insist further on it.'

Our author adds, that another important circumstance resulting from the captivity of queens is, that they are in a better condition to fly when the bees have given them liberty, and are therefore capable of profiting by the first moment of sunshine to depart at the head of a new colony.

Dangers during Swarming.

The capture of the queen, when a swarm has settled on some bush or tree, is, it should be added, the first step towards lodging a swarm in a new hive. If she be placed in it, with two or three bees, the rest will soon follow. A strong glove will enable any one to handle the bees without risk, as they are less disposed to sting when they are swarming than at other times. It sometimes happens, however, that a swarm may settle on the person of any individual who may be near, in which case presence of mind is absolutely necessary for the preservation of life. The following anecdote, related by Thorley, is strikingly illustrative of what has now been advanced:

'One of my swarms settled among the close-twisted branches of a codling-tree; and not to be got into a hive without help, my maid-servant, being in the garden, offered her assistance to hold the hive while I dislodged the bees. Having never been acquainted with bees, she put a linen cloth over her head and shoulders to guard and secure her from their swords. A few of the bees fell into the hive, some upon the ground, but the main body upon the cloth which covered her upper garments. I took the hive out of her hands, when she said that the bees had got under the covering, and were crowding up towards her breast and face, which put her in a trembling posture. When I perceived the veil was of no further service, she gave me leave to remove it. This done, a most affecting spectacle was presented, filling me with the deepest distress and concern, as I thought myself the unhappy instrument of drawing her into so imminent hazard of her life. Had she enraged them, all resistance had been vain, and nothing less than her life would have atoned for the offence. I used all the arguments I could think of, begging her, with all the earnestness in my power, to stand her ground, and keep her present posture. The bees had now got in a great body upon her breast, about her neck, and up to her chin, and I began to search among them for their queen. I immediately seized her, taking her from among the crowd, along with some of the commoners, and put them together into the hive. Here I watched her for some time; and as I did not observe that she came out, I conceived that the whole body would quickly abandon their settlement; but instead of that, I soon observed them gathering closer together, without the least signal for departing. Upon this I immediately reflected that either there must be another sovereign, or that the same was returned. I directly commenced a second search, and in a short time, with a most agreeable surprise, found a second, or the same. She strove, by entering further into the crowd, to escape me; but I reconducted her, with a great number of the populace, into the hive. And now the perilous scene began to change to one infinitely more pleasing and agreeable. The bees, missing their queen, began to dislodge and repair to the hive, crowding into it in multitudes, and in the greatest hurry imaginable; and in the space of two or three minutes, the maid had not one single bee about her, neither had she received so much as one sting, a small number of which would quickly have stopped her breath.'

ARTIFICIAL MANAGEMENT—THE APIARY.

The artificial management of the hive forms, in some measure, a distinct branch of the present subject. In the

first place, the local situation of an apiary, or accumulation of bee-hives, has been held of especial consequence.

Site of Apiaries.

The hives must be sheltered in a particular manner from the action of high winds. A wall or hedge is not sufficient to yield the requisite protection; houses or lofty trees are necessary to insure it. The reason of this is, that the bees, returning homewards, require a calm air at a considerable height above their dwellings, otherwise, when they attempt to alight, they are dashed to the ground and killed, their exhausted strength disabling them from coping with a wind of any force. A low position, enclosed with woods, suits them best. Bees drink much, and a fountain or brook is essential to them; deep pools or cisterns very often cause their death by drowning. Shallow troughs, filled with moss or floating wood, are recommended as a substitute for shallow rills. It is an error, according to the experienced bee-keeper De Gelieu, to suppose that hives should be placed full in the sun. Bees, he says, live and thrive in shady places of moderate and uniform temperature; hence their partiality for forests. Besides, exposure to all the extremes of the solar heat melts and spoils the honey. In fine, if exposure to the sun be beneficial at all, that exposure should last only for a comparatively short time, or from about ten o'clock till noon. Hives should not be placed on upper floors, on account of the increased danger from wind. At the same time, a bee-house ought to be so made as to cause a free passage of air, though not of strong currents, at all periods, with openings both anteriorly and posteriorly. A covered shed or veranda is perhaps the best form of a bee-house, yielding both a shade from the heat and shelter from the wet. Where hives are simply placed on open stands, these should be about sixteen inches from the ground, and each three or four feet apart. Shifting

is condemned by almost all observers, as very hurtful to the bees. Quiet is also necessary to their successful operations; and it has been found that they do not thrive well in the neighbourhood of smithies, mills, steam-engines, and the like, partly, we believe, on account of the noise, and partly owing to the smells emitted from such works.

As to the district of country, that of course will always be preferable which yields such vegetable productions as the insect can turn to account. 'Large heaths, sheltered with woods,' says the *Naturalist's Library*, 'are extremely productive of honey, as the wild thyme and other flowering plants with which they abound are not cut down by the scythe; and the heath itself remains in bloom till late in the season. The plane-tree, the whole willow tribe, the furze or whin, the broom, especially the Spanish kind, furnish a rich store both of honey and farina. Bees do not feed indiscriminately on every species of flowers; several of the most splendid and odoriferous are wholly neglected by them, while they select others, the flowers of which are extremely small, and not apparently possessed of any valuable qualities. Moreover, they give a decided preference to those spots where a *great quantity* of their favourite flowers grow together. On the continent, fields of buckwheat afford a copious supply, though the honey extracted from it is of a coarser kind; and in our own country, the white clover will, in fine weather, be found thronged with them, while scattered plants that afford more honey are neglected. When a variety of bee-flowers flourish in the same field, it is said they will first collect from those which furnish the best honey; if, for example, several kinds of thyme grow together, they prefer the lemon variety, which is of a sweeter and richer fragrance.

'But while mainly depending, as they must always do, on the natural products of the country, the bee-master will do well to supply his favourites with such flowers, &c., as are not found growing spontaneously in his neighbourhood. In addition to the gooseberry, currant, and raspberry bushes, and the several orchard trees, the flower-borders in his garden should be well stocked with snow-drops, crocuses, wall-flower, and, above all, the mignonette, which affords honey of the richest flavour, and which continues flowering till the near approach of winter. The rich melliferous blossoms of the *Buddlea globosa*, too, the bees are very fond of; and some of the *Cacalia* tribe afford an ample store. "The *Cacalea suaveolens*," says Darwin, "produces so much honey, that on some days it may be smelt at a great distance from the plant. I remember once counting on one of these plants above two hundred painted butterflies, which gave it the additional appearance of being covered with additional flowers." Besides these, the plants of borage and viper's bugloss yield a very considerable quantity of the rich liquid. The former is eagerly resorted to by the bees; it is an annual, and blossoms during the whole season, till destroyed by the frost. In cold and showery weather, the bees feed on it in preference to every other plant, owing to its flowers being pendulous. The bugloss appears as a troublesome weed among corn, and grows on dry soils in great profusion; it is a biennial plant. Turnips, particularly the early garden kind, should be sown, and allowed to remain in their beds during the winter; and they will in consequence, by their early flowering, afford a seasonable supply of farina, and also a small portion of honey early in spring. The whole cabbage tribe also may be made to contribute their share; and mustard, when sown in successive crops, will continue to blossom for many weeks together.'

Hives.

The important question of the size, form, and materials of the hive, or artificial habitation, has of course received much attention. Whatever be the form adopted, it is found that bees accommodate their labours to it, and fashion their combs of honey accordingly.

Straw hives, of which a sketch is given in the preceding page, are those most commonly used in cottage-gardens; and being easily and cheaply constructed, they still maintain their place, though much better habitations could be suggested. They are of a roundish form, ordinarily measuring about twelve inches deep and nine inches wide in the lower part. Made of unbroken rye straw, or any other straw of a strong and elastic fibre, and well bound, they will, if tolerably well sheltered, last many years. It is customary to place sticks across the interior, from an idea that such are necessary for supporting the combs; but Mr Taylor, in his *Bee-keeper's Manual*, combats this opinion. 'The sticks,' observes that intelligent writer, 'are only an annoyance to the bees; and there is little fear of the combs falling, except in very deep hives: at anyrate, it may be prevented by contracting the lower part a little. The best way of doing this is by working a wooden hoop inside the bottom band of the hive, as recommended by Dr Bevan, who says, "it should be perforated through its whole course, and the perforations made in an oblique direction, so distant from each other as to cause all the stitches of the hive to range in a uniform manner." The hoop gives greater stability to the hive, preserves the lower edge from decay, and affords facility in moving it. I advise a circular piece of wood (turned with a groove at the edge to retain it in its place) to be worked into the crown, having through it an inch and a half hole. With a little ingenuity, the bees may be fed through this opening—a better method than the ordinary one at the bottom of a hive. A piece of wood or tin will commonly cover the hole; but at times, and especially in winter, it may be used for the purpose of ventilation, and allowing escape to the impure air of the hive. In this case, a bit of perforated tin or zinc should be placed over it, which, when stopped up by the bees, can be replaced by a clean one. An earthen pan is a common cover to a straw hive, and this may be slightly raised by wedges on the four sides, to permit a small space underneath. Of whatever material the outer covering consists, it must project so far on all sides as to protect the hive from moisture. This cannot be too much guarded against; and whether of wood or straw, hives ought to be well painted at the beginning, and periodically afterwards.'

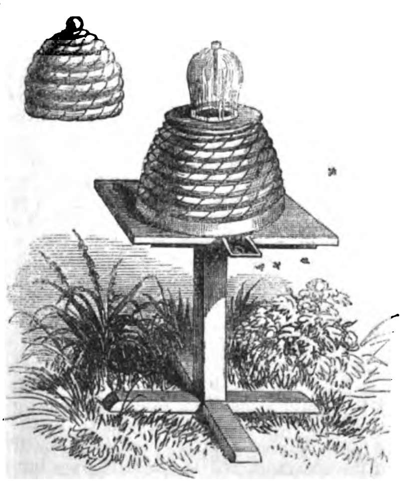
Wooden hives are superior to those made of straw, the square shape being better adapted for the deposit of combs than the round form. Mr Taylor's observations may be likewise quoted on this important point. 'It matters not much of what wood the boxes are made, provided it is sound, thoroughly seasoned, and well put together. Different opinions are entertained as to the best size of bee-boxes, but I think that much must depend on the number of bees they are to contain, and on the honey locality; there must also be a reference to the proposed mode of working them; for where no swarming is permitted, a larger hive may be advantageously used. A good size is twelve inches square and nine inches deep within; the thickness throughout being not less than an inch. The top of the box ought to project on all sides nearly three-quarters of an inch, for better protection and appearance, and as affording convenience for lifting. On the top, a two-inch hole should be cut in the centre, for placing a bell-glass, and for the purpose of feeding; and another hole, to receive a ventilator, may be made near the back window, that position being better for inspection, and less in the way of the bees, than the centre of the hive, which is, or ought to be, the seat of breeding, and should not be disturbed. A window may be placed at the back and front, five inches high, and six or seven inches wide. The best and neatest way of securing the windows that I have seen, is by a sliding shutter of zinc.'

To these explanations it should be added, that the

hive of either form must be placed on a clean wooden floor or board; and if there be several hives together, each should have its own separate floor. Do not cement the hives to the board, that being a duty which the bees will themselves perform; all that may be given is a slight luting of clay, or any easily removable material. The entrance to the hive requires to be small, a little larger than a shilling, but rather wider than deep, and ought to be at the lower edge of the hive, on the side which is exposed. Numberless have been the plans invented to enlarge hives as may be required, both to permit of the greater accumulation of honey, and to render swarming unnecessary. Caps or hoods are the simplest of these inventions. In order to use caps, hives must have a stoppered hole at the top. A small additional hive, of light structure, is placed over this at the proper time, the stopper being removed. This serves as a second magazine for honey. Storied hives are merely hives made originally with one or two stories, for the same end. Wildman's hive, the Grecian hive, and Lombard's hive, are specimens of hives made on this principle. Collateral hives again, such as Nutt's, effect the same ends by being placed side by side, and giving increased accommodation, when necessary, either for swarms or stores.

Use of Caps.—It will be observed from these quotations, that experienced apiarians, who work on a large scale, now employ for the most part hives so contrived as to remedy all the inconveniences resulting from the straggling of swarms and the old custom of killing by brimstone. As the use of single straw hives, however, formed upon the simplest plan, still prevails among those who have but one or two hives in all, the cap may be regarded as the easiest means of affording enlarged accommodation in such cases, and the mode of taking away the honey from it is very plain and easy. It is only necessary to remove the cap, invert it, and cover it with a handkerchief, leaving a little opening on one side. A few taps will cause the bees to quit the cap and return to the hive, after which the honey can of course be readily removed. This may be done frequently in the same season. De Gelieu mentions, that in one season he drew from one of his straw hives that did not swarm seventy-two pounds of fine honey-comb, by merely emptying the caps as they were filled.

One of the cheapest and simplest forms of the capped straw hive is the Improved Cottage-hive, exhibited in



Milton's Improved Cottage-hive.

the Crystal Palace, in 1851, by Mr Milton, and which received a prize medal. It is simply a straw hive of the usual dome-shape, with a wooden hoop round the bottom. The projecting landing-place is sloping and sunk, so as to form an entrance without cutting the edge of the hive. An opening of two inches diameter is left in the top of the hive, and over this is fastened a flat board, not so large as the bottom diameter of the hive, with a similar aperture. The empty space between the top of the hive and the board is filled up with cement or putty. The cap is a smaller hive, adapted to stand on this board, and may be used alone, or to cover a bell-glass. The hole in the board is kept closed by a bung until the bees give indications of swarming, or of having filled the hive; the bung is then withdrawn, and the bees ascend and fill the glass, or the small hive with pure honey. When it is filled, a knife is passed below to detach any combs that may be adhering to the board, and it is then removed, and another cap put in its place. The bell-glass is represented in the cut with an aperture at top, through which a perforated zinc tube descends, for the purpose of ventilation.

Union of Swarms.

It is strongly recommended by experienced men, that swarms should be more often united than they are. Five thousand bees are estimated to weigh a pound; and, according to most bee-keepers, a swarm ought to weigh nearly four pounds. As a hive often casts off successive colonies, each far below this weight, it then becomes proper to unite two or more of them; seeing that one strong population supports itself better, and is incomparably more profitable, than several feeble colonies, which must be frequently in want of assistance. To those who keep bees on a small and cheap scale, convenience also dictates the junction of swarms in such cases. De Gelieu thus describes his mode of practice: 'When two small swarms come off the same day, I gather them separately, and leave them at the foot of the tree or bush on which they have alighted. Towards evening, I spread a table-cloth on the ground, on which, by a smart and sudden movement, I shake all the bees out of one of the hives, and immediately take the other and place it gently over the bees that are heaped together on the cloth, and they instantly ascend into it, flapping their wings, and join those which, not having been disturbed, are quiet in their new abode. Early next morning, I remove this newly united hive to the place it is destined to occupy. This doubled population works with double success, and in the most perfect harmony; and generally becomes a powerful colony, from which a great profit is derived. Two feeble swarms may be united after the same manner, although one of them may have come off some days later than the other, and the first may have constructed combs; taking care, however, not to make the first one enter the second, but the second the first, as the bees will ascend more readily to join those that have already begun to make honey and to hatch brood; and next day they will proceed together with increased ardour with the work which the first had already begun, and which will now advance more rapidly from the increase of the labourers. It is to be understood that, after this union, the hive should be placed early next morning in the same place where the oldest of the swarms has already passed some days.' On many occasions, the circumstance of two queens passing out at once, is the cause of a colony going off in two halves, and the removal of one of the queens is necessary, to facilitate their cordial junction into one community.

Besides the union of young swarms, it is often advisable to reunite weak swarms with their parent stocks, to unite weak stocks with each other, or even to add to some weak community a portion of one more numerous and healthy. In either case the object is the same—namely, to obtain well-filled, strong, and consequently more active hives. The three usual modes—we abridge partly from Bagster—by which union has been attempted, and, indeed, their advocates say accomplished,

are—fuming them, immersing them in water, and aspersing them with sugared or honeyed ale. To these we may add a fourth—namely, operating upon their fears, by confining them for a time, and then alarming them by drumming smartly upon the outside of their domicile. It was operating on their fears that enabled Wildman to perform such extraordinary feats with bees. When under a strong impression of fear, says he, they are rendered subservient to our wills to such a degree as to remain long attached to any place they afterwards settle upon, and will become so mild and tractable, as to bear any handling which does not hurt them, without the least show of resentment.

The neatest and most scientific mode with which we are acquainted of uniting weak families together in harmony, was invented by the Rev. Richard Walond, whose experience in the management of bees, for nearly half a century, entitles his opinions concerning them to great respect. His theory and practice upon this subject are as follows:—'Bees,' says he, 'emit a peculiar odour, and it is by no means improbable that every family of bees emits an odour peculiar to itself; if so, as their vision seems to be imperfect, and their smell acute, it may be by this distinctive and peculiar odour that they are enabled to discriminate betwixt the individuals of their own family and those of a stranger hive. Upon this supposition, if the odours of two separate stocks or swarms can be so blended as to make them completely merge into each other, there will then probably be no difficulty in effecting the union of any two families that it may be desirable to unite.' To accomplish this end, therefore, Mr Walond had recourse to a very ingenious contrivance: he procured a plate of tin, the size of a divider, and thickly perforated with holes, about the size of those in a coarse nutmeg-grater. Having confined, in their respective hives or boxes, the two families to be united, and placed them over each other, with only a divider between them, he introduced his perforated tin plate upon the divider, which was then withdrawn. Immediately the bees began to cluster with hostile intentions, one family clinging to the upper, the other to the under side of the perforated plate; when, after remaining in this state for about twenty-four hours, they had so far communicated to each other their respective effluvia, and so completely commixed were the odours in both hives, that on withdrawing the perforated plate, the bees mingled together as one family: no disturbance was excited, but such as arose from the presence of two queens, the custom being always in such case to dethrone one of them. According to Huber, this is effected by single combat between the queens. Keys has observed that these incorporations seldom turn to account unless they be effected in summer; and when it is considered that the principal gathering months are May and June—excepting in those neighbourhoods that abound in lime, sycamore, and other trees that are apt to be affected with honey-dew—we cannot of course expect them to be very successful.

This plan of the Rev. Richard Walond is very ingenious, and unquestionably, on his authority, proves our position—that smell is one of the senses used by the bees to detect a stranger—and leads us to doubt the authenticity of accounts which state that the system of union by means of driving has been uniformly successful. Our aim, however, is not to condemn, but to shew that fumigation is the easiest and surest operation. The plan is as follows: In autumn, three or four fuzz-balls or puff-balls—a kind of fungus growing in the meadows, and commonly called the 'Devil's Snuff-box'—must be pulled before they are fully ripe. These must be thoroughly dried in an oven, and kept dry till wanted. A round box, made of thick tin, without any solder, must be provided. This box must be about two inches in diameter, and an inch and a half deep, with a conical movable top, about an inch and a half high, perforated with holes. The bottom must also have three holes in it. With this box, and a piece of a fuzz-ball about the size of a hen's egg, in readiness, the operator commences by fixing an empty hive, of the same size as that from which he intends to take the bees, securely, in an inverted position, in a pail or some other convenient utensil. A sharp-pointed stick having been stuck into the empty hive, so as to stand upright within it, the box is fixed thereupon by inserting the stick into one of the holes in its bottom. The piece of fuzz-ball is then lighted and put in the box, over which the conical lid is placed. The hive from which the bees are to be taken is then placed over the empty hive and the burning fungus. To keep all close, a wet cloth is put round the place where the two hives join. In a minute or two, the bees may be heard dropping heavily into the empty hive, where they lie stupified. After a short lapse of time, the full hive may be tapped, to cause the bees to fall faster. On removing the upper hive, the bees from it will all be found lying quiet at the bottom of the lower one. The queen may be taken from them and placed under a glass with a little honey on a small piece of comb. The stupified bees must then be sprinkled freely with a thick sirup made of sugar and ale boiled together. The hive containing the bees with which it is intended to unite the stupified bees, must now be placed on the top of that containing the latter, just as the hive was from which they have dropped. A cloth must be closely fastened round the two hives, so as to prevent any of the bees from escaping. The hives in this position must be put aside, where they will not be likely to be thrown down or disturbed. The bees in the upper hive, attracted by the scent of the sirup, go down and begin to lick the sprinkled bees clean. The latter gradually revive, and all get mingled together, and ascend quietly in company to the upper hive, where they dwell as if they had always been one family. The two hives should be left undisturbed for twenty-four or thirty hours, at the end of which the upper hive is to be removed and placed immediately on the spot from whence it was taken. The object of taking the queen away is to avoid all risk of disagreement. It is, however, recommended to preserve her as long as she will live, lest any accident should happen to the sovereign of the other community.

Summer Management of Bees.

The feeding of bees at different seasons is an important point to the bee-keeper. In summer they feed themselves, and of course a good supply of the requisite material is then essential to their well-doing. The most highly cultivated districts are not so favourable to bees as those in which wild heaths, commons, and woods prevail; or where white clover, saintfoin, buckwheat, mustard, and cole-seed, are produced in abundance. Bee-keepers, however, may do something to further the supply of summer food by growing near their apiaries a selection of such plants as we have recommended under a previous section. But on the natural products of the country, generally speaking, bees must rely for summer food, if the weather be such as to permit of their gathering it. Should a succession of coarse bad weather occur, however, at the beginning of summer, and particularly after a swarm has entered a new hive, most apiarians think it essentially necessary to give honey, or a sirup of sugar and water, to the newly hived stock. If no proper brook or fount be at hand, water should always form a part of the summer provision. The bees being at full work in this season, the door of the hive should be opened to its whole extent, and not closed, as is more or less requisite at other times. In the hives formed upon improved plans, ventilators constitute a part of the apparatus, and thermometers are introduced to regulate their use. Though these are valuable adjuncts certainly, they are not indispensable, seeing that the bees, as already mentioned, contrive to ventilate to some extent for themselves. Where artificial ventilation can be effected, it is recommended that the temperature

should be maintained at from 65 to 80 degrees of Fahrenheit. It is recommended, on evenings when the moths are numerous, to place a small grating before the hive; and it will also be advisable to destroy any wasps, spiders, earwigs, or other insects which may settle near the hives.

Autumnal Management.

The autumnal period has long been the most calamitous for bees, not through the injuries of enemies or weather, but from the improper management of bee-keepers. After the carcasses of the drones, strewn in multitudes before the hive, have indicated that, with the beginning of August, has come the close of the rich honey season, the bee-keeper deems it time to take from the hive the reward of his care and attention. The use of storied hives or extra boxes renders it easy to take away a portion of honey early in the season, and this is called *virgin honey*. Even with a common straw-hive, it has been found possible to take away the honey, and retain the bees in the hive. Wildman, the famous experimenter on bees, recommended that the hive should be taken into a dark room, and there struck repeatedly till the bees are forced to ascend into an empty hive. The combs are then cut out with a thin knife, and the bees finally returned to the old hive. But this plan is seldom pursued, being at once dangerous and destructive to the brood combs.

It is generally reckoned advantageous to change the pasturage for a week or two before taking the honey-harvest. About mid-autumn, the ordinary food of bees begins to fail, and their stock of honey to decrease daily. By a removal of three weeks to a heathy district, a hive not only loses nothing, but frequently gains as much as ten or twelve pounds of honey in ordinarily favourable circumstances. So well is this known by bee-keepers near Edinburgh, that one shepherd on the heathy Pentland Hills receives in charge several scores of hives annually, for the heath-feeding.

Honey-harvest.

After the autumnal accession of honey has been obtained, and the bees have been brought home again, the question comes to be, in what manner the harvest should be reaped. By partially depriving each of a portion of comb, and leaving some for food? By suffocating one half the communities, taking their entire honey, and leaving the other hives with their honey untouched, to serve as stock? Or, finally, by removing the bees from one half the hives to the other half, forming united stocks, and acquiring all the honey of the evacuated ones? These three plans are known by the several names of *partial deprivation*—commonly and most easily practised with improved hives, as already described—*suffocation*, and *union of stocks*. 'Partial deprivation,' says the *Naturalist's Library*, 'consists in appropriating early in the season a portion of the stores. In preparing prospectively for thus sharing in the products of the hive, the cultivator who pursues the storifying system, immediately after the swarming season is over, adds another story or box to the two of which his hive consists, placing it undermost, or, as it is called by some bee-masters, *nadiring*. The brood combs contained in the uppermost story will, as the young bees are hatched, be quickly filled with honey, and may be removed about the beginning of August. The top cover is then replaced on the next story in position, which was originally the lower, and is now the upper. In ordinary seasons, the bees will have ample time to lay in sufficient food for winter and spring use, after the abstraction of this portion of their stores. As the combs of the upper box are frequently found adhering by their lower extremities to the bars of the next, it will be necessary before removal to separate them by means of a very thin long-bladed knife, or a fine wire drawn through the hive at the point of junction. The operator will next expel the bees from this box or story, by lifting the top cover, and blowing in a little smoke, which will cause the inhabitants to retreat quickly to the lower regions. The box may be then taken away, without the operator running the risk of the slightest annoyance. The honey found in this removed box will not be all honey of the current season, and consequently is not so delicately fine. It is also sometimes found mixed with, or rather deposited above a layer of farina. Should it be wished, therefore, to obtain a supply free from these impurities, the empty story which is added may be placed *above*, instead of *below* the original stock, and the honey will thus be of a superior kind. This mode of operating is called *super*-ing, in contradistinction to *nadir*-ing; and we understand that Dr Bevan practises the latter only with young swarms, and the former with those of preceding years.

'Partial deprivation has never yet become general, because it is liable to frequent failure, even in improved hives, and because the full benefit is not derived from it at the very commencement of the system. The liability to failure, the first of the objections stated, is owing in most instances not to the *mode*, but to the *period* of the operation. According to the too common practice of those who are friendly to deprivation, a portion of honey is abstracted from the hives about the beginning or middle of September; and the owner compliments himself on his moderation in being content with a part instead of the whole, and on his humanity in saving the lives of his industrious favourites; while in nine instances out of ten he finds, on the arrival of March, that his moderation and humanity have been altogether unavailing, and that he has saved them from a violent death by suffocation, only to expose them to the more tardy, but not less cruel death by starvation. Whereas if deprivation takes place soon after the swarming season, as already recommended, and is managed with discretion, the issue will be very different, and ultimately more profitable to the owner, than the almost universally practised mode by suffocation, which is too well known to need description. The latter system may yield a greater return in proportion to the hives operated upon; but in the former there is a much greater number of hives available. For example, suppose two apiaries, each containing five stock hives at the end of July, exclusive of as many swarms recently thrown. The owner of the one, practising the depriving system, takes from each of his stocks 10 pounds of honey, making an amount of 50 pounds as his honey-harvest. The owner of the other, an abettor of suffocation, proceeds in September to smoke his five old hives, and receives from each 25 pounds of honey, making an amount of 125 pounds as his honey-harvest—between two and three times the quantity of the other. In the following year, the depriver has his five old-stock hives, and the five swarms now become stocks also; from the whole ten he now takes 100 pounds of honey, while at the same time his apiary is augmented by the addition of ten new swarms, making twenty for the following year; while his rival possesses only his former number of five, yielding 125 pounds. In the next year—that is, two years from the commencement of the comparative trial—the depriver has twenty stock hives, yielding 200 pounds, and so on by a geometrical ratio; while the other remains at his original 125 pounds. This calculation is made on the supposition that each owner takes but one swarm from each stock, and without making any allowance for losses and failures which will affect the produce of both in honey and bees, but to which both are liable.'

The writer of the treatise now quoted from, proceeds to point out the advantages of the humane principle of sparing the lives of these useful insects. 'It is pitiable to reflect, that the small degree of additional trouble required in uniting them, should prove so effectual an obstacle to this conservative practice. Yet the operation with each hive so treated need not occupy

more than fifteen or twenty minutes. In the evening, when all are quiet, turn up the hive which is to be operated upon, fixing it in a chair from which the stuffed bottom has been removed; place an empty hive above it, wrap a cloth round the point of junction, to prevent the bees from coming out and annoying the operator; then, with a short stick or stone in each hand, beat round the sides, but *gently*, for fear of loosening the combs. In five minutes, the panic-struck insects will hastily mount into the empty hive, with a loud humming noise, expressive of their trepidation. The hives are then separated—that containing the bees is placed on its usual pedestal, and the other containing the honey is carried off. The union is next to be effected. Turn up the stock hive, which is to receive the addition to its population; with a bunch of feathers, or a small watering-pan, such as is used for watering flower-beds, drench them with a solution of ale and sugar, or water and sugar, made a little warm. Do the same to the expelled bees; and then, placing these last over the stock, mouth to mouth, a smart rap on the top of the hive will drive them down among the bees and combs of the undermost hive. Place this last on its pedestal, and the operation is completed. The strong flavour of the solution will prevent them from distinguishing between friend and stranger; and their first movement, after recovering from their panic, will be to lick the liquid from one another's bodies. This mode of operating is applicable to all kinds of hives.' (See previous section on the Union of Swarms.) With regard to the two queens, one would assuredly kill the other in a very short time; but the best way is to remove one of them before union.

One argument employed by advocates of the plan of suffocation by introducing the fumes of brimstone or other noxious effluvia is, that by the union of stocks you have an immense number of mouths to feed, of which the killing plan relieves you. Only inexperienced bee-keepers, however, could use this reasoning, De Gelieu having discovered the remarkable fact, that the increase of numbers in the winter hives is far from producing a proportionate increase of consumption. From fifteen to twenty pounds of honey, or from three to four pots, are requisite for the winter maintenance of a single hive of ordinary strength, with which the plan of union has not been practised. De Gelieu placed such a hive, with such a store, beside one into which three full communities had been introduced; and he found, on weighing the latter in the spring, that its inhabitants had scarcely used one pound of honey more than those of the single-stocked hive. The experimenter even went further. To a hive already amply stocked, he added the swarms of *four* other hives, and found, on weighing it in the spring, that 'the total diminution of honey did not exceed three pounds more than took place in ordinary single hives.' Had they not been thus united, he says, each of these stocks would have cost him much more honey than they were worth, and indeed the most of them 'would to a certainty have perished.' The cause of this strange fact, by which nature seems to point to the plan of autumnal unions as the best possible for both bees and bee-keepers, is yet unknown.

The combs, by whatever process procured, should be deprived of the honey at once, while a natural warmth remains in them. Various kinds of drainers have been used for separating the honey, and keeping it as much as possible from the external air. The honey which runs off naturally without breaking down the combs, and passes through muslin, is held to be the finest. A second kind is procured by cutting the combs in pieces, and letting the honey pass through a drainer, under exposure to a gentle heat. A third quality is procured by subsequently putting the combs in a vessel placed on a fire; the product, strained through canvas, is used in feeding bees. The separated wax of the combs is introduced into a woollen bag, firmly tied at the mouth, and put into boiling water. The pure wax oozes through, and is skimmed off the surface, where it floats. It is then to be allowed to cool slowly. The best honey is supposed to be that formed from heath. The famous bees of Hymettus were nourished by that plant.

Honey is used as a condiment at the table, and is also employed in medicine. Its value is rarely under 2s. a pound. In Britain alone, about £120,000 is annually spent for foreign supply; and if we add to this a large home production, and consider that in other countries the article is even more liberally made use of, we shall arrive at some conception of the economical value of the bee. But it is not the honey alone; we import 10,000 hundredweights of wax each year; and when we state that the price varies from £5 to £10, 10s. a hundredweight, it will be seen that its value is all but equivalent to that of honey.

Winter and Spring Management.

In winter and early spring, bees require to be tended with great care. In the case of those hives which have been entirely deprived of their honey, systematic feeding is of course indispensable in winter; but few bee-keepers of any experience ever willingly follow any other plan than that of leaving to bees a winter supply of their own produce. Some bee-keepers remove their hives into the house in winter; but this seems an unwise practice, as the bees must then be kept continually in confinement. Though the door of the hive should be carefully narrowed or shut up in very cold weather, at which time every bee that issues perishes, yet advantage should be taken of every fine day to let them abroad. On this point, however, great difference of opinion exists—many contending that the bee naturally becomes torpid in winter, object to their exposure to sunshine altogether, and for that purpose recommend screens and coverings. One thing is certain, that a moderate degree of warmth is necessary, and that this warmth should be as equable as possible; while at the same time there should be the most thorough precautions against damp. It is damp more than cold which kills our hives in winter; and he who protects them from cold and wet by a thorough covering of straw, fern, flax refuse, or the like, plastered over with Roman cement, is sure to have the healthiest apiary.

Proceeding on the 'dormancy' theory, a singular device for winter preservation has been resorted to by some bee-masters—namely, *burying the hives*. When this is to be attempted, the hive should be buried in a cool, dry, shady place, among leaves about a foot deep, and the interment should be performed during the first or second week of November. Mr Briggs, who first made public this device, records the following experiments:—'A friend in the vicinity of Hitchin buried a hive of bees in the first week of November, about a foot deep among dry leaves, &c., and disinterred it in the last week of February, when it was just *two pounds lighter than it was in November, and the bees in a lively and healthy state*. Another person, residing in Leicester, immured a hive of bees in the earth, four feet deep, in the second week in November, and at the end of January it was removed, and weighed *only three ounces less than it did before it was buried*. The above experiments,' adds Mr Briggs, 'are worthy of further attention; and I would recommend that a shed, having a northern aspect, and which is as dry as possible, would be a suitable place for further trials. The principal points by which there might be cause for fear of failure, would, as in other cases, be from dampness, disease for want of fresh air, and attacks from vermin. To prevent the former, I would recommend that the hives be placed on a long frame of wood, covered by a web of closely worked wire, and raised a few inches from the ground, the ends of which should communicate with, and be occasionally opened to, the fresh air. A long tube should also be placed from the hole at the top of each hive to the open air of the shed, from the upper end of which any

dampness might be condensed by bell-glasses, and conveyed away, as already directed. The materials with which the hives are covered and surrounded should consist of dry leaves pressed closely together, or dry and powdered charcoal or cinders, and may be several feet in thickness, to preserve the bees in a cool and torpid state, and at a regular temperature, in which state they should be kept as *dry*, *dark*, and *quiet* as circumstances will permit. As the spring approaches, the winter coverings should be gradually removed, and the hives placed in their summer situations. Small quantities of food should then be supplied as occasion requires, until the gooseberry and currant bushes are in bloom, at which time it may in general be considered that their winter is past.'

Where feeding is necessary, the following rules have been laid down for the management of common hives in winter and early spring:—Bees must be fed only when the weather is fine and warm, to prevent the temperature of the hive from being injured; and a large quantity should never be given at once. The quantity of food which ought to be given to a hive may be calculated in the proportion of two pounds a month; but if the weather be very cold, a less quantity will suffice. When a hive is fed in the spring, it should always be after sunset, when the bees have returned from the fields; otherwise the most disastrous consequences may ensue, from the robberies committed by the bees of other hives. If fed in the morning, it must be before sunrise, and the entrance instantly stopped, to keep out depredators; for as bees leave the hive on the very first appearance of daylight, a later period would prevent the return of those which had left the hive previous to the entrance being secured.

Relative to the substances which are proper for the feeding of bees, many different opinions exist; but the following may be considered among the most beneficial as well as economical articles of diet:—To two quarts of good ale put one pound of moist sugar; boil them until the sugar is wholly dissolved, carefully skimming it; when it is cold, it will be found of the consistency of honey, and it may be given to the bees in the following manner: If the bees are in the plain cottage-hive, an eke of the same diameter as the hive must be provided, and from three to four hands in height. When the sun is set, and the bees have retired, let the hive be gently raised, and the eke placed on the stool; then, having filled a soup-plate with the food, place it in the eke, and put down the hive. To prevent the bees being drowned in the liquid, it is necessary to place some straws over the plate, and over the straws a piece of paper, either thickly perforated or cut into nicks; these nicks, however, must not run parallel with the straws, but either across or diagonally; the entrance must then be closed, and the plate removed on the following morning, when the whole of the liquid will have been transferred to the combs. In order to avoid lifting up the hive for the purpose of feeding, some recently invented hives have a drawer under the bottom board, into which a shallow vessel containing the food is put, access to it being opened for the bees by drawing out a tin slide in the bottom board. The food is covered with a float of thin cork or wood, pierced with holes. In others, the feeding-saucer is placed on the top of the hive, under a bell-glass, and the bees allowed to ascend through an aperture.

Diseases and Enemies of Bees.

Bees, according to the conclusions of De Gelieu, after sixty-four years' experience, have 'no real disease; they are always in good health as long as they are at liberty, and when they are warm enough, and have plenty of food.' In early spring, however, they are found liable to an affection called dysentery, which is known by the marks on the board of dark-coloured evacuations, by the offensive smell, and by the frequent deaths. This disease certainly results, in most cases, from long confinement in a damp and impure air. By lifting the hive to expel the vitiated air, scraping, washing, and drying the board, and removing the dead bodies, the complaint, says Mr Taylor, may soon be remedied even in the most extreme cases. Rosemary, mixed with honey and water, has been recommended as a cure; but the experienced apiarian mentioned, conceives all dietetic remedies to do more harm than good. A little chloride of lime, he suggests, may be used beneficially in washing the board. One point should be noticed here, that exposure to the sun is held decidedly injurious to the hives in winter. This caution is necessary, as bee-keepers, when they suspect dampness, might fall into an error on this score. While on this subject, we may also mention a new remedy, which is said to have been adopted on the continent with success. When dysentery begins to shew itself in the apiary, the bee-keeper prepares a sirup composed of an equal quantity of good wine and sugar, which is administered to the bees in every hive, either by pouring it into the cells, or placing it within the hive in a saucer, or any other shallow vessel.

About the end of spring, another disorder sometimes makes its appearance, which Du Carne de Blangy calls vertigo. This is supposed to be occasioned by the poisonous properties of certain plants on which they feed. The symptoms are manifested by a dizzy manner of flight, by their involuntary startings, falls, and other gestures in attempting to perform their usual operations, or in approaching the hive, and by the lassitude that succeeds these symptoms. This distemper has been hitherto found incurable. Bees, according to the same authority, are liable to a third distemper, the symptoms of which are swelling at the extremities of the antennæ, which become also much inflamed, and of a yellow colour; the head assuming shortly after the same tint, the bees lose their vivacity, and languish till they die, unless a proper remedy be applied. In France, they give them Spanish wine for this disorder. There is still another distemper which sometimes makes its appearance among bees, for which the continental agriculturists administer Spanish wine, as in the former case. This is a kind of pestilence, by which many of the insects are cut off. It happens when the queen-bee has placed the eggs carelessly in the comb, so that the larvæ perish in the cells, or that they are killed by the cold or otherwise, when numbers die and infect the rest. The only attention requisite in this case is to remove the infected combs, perfume the hive with aromatic plants, and give them the wine to sip, as already mentioned, in order to strengthen and restore them from their sickness.

A few hints from Gelieu and others, respecting the chief foes of the bee tribe, may be useful to bee-keepers. The former authority, after observing that the possessors of bees, often from an ignorant excess of care, are among their greatest enemies, says: 'Ants are their least dangerous enemies: true, the bees cannot sting them to death, because they are small and well defended with armour, but they seize hold of them with their teeth, and carry them to a distance. Had they not this means of getting rid of them, their colonies could not exist in the vast forests full of ants' nests, and where they thrive so well, in spite of the horrible massacres that annually take place.

'Moths are little known, and never injurious, in the high valleys, nor on the mountains; but they attack and destroy a vast number of hives in the plains or in the vineyards, where they are a great scourge. Huber discovered that the *Sphinx atropos*, or death's-head moth, was one of the most destructive of this tribe. As soon as a moth has penetrated a weak hive, it establishes itself in a comb, envelops itself in a silken web, multiplies rapidly, consuming the wax, and spreading its destructive galleries from side to side, until, arriving at a certain point, the evil has scarcely a remedy. The only means of saving the colony is to imitate the surgeon, who cuts off a diseased limb to save the other—every

bit of infected comb must be cut out, leaving only those occupied by the bees. The bees must then be liberally fed, by giving them every evening as much honey as will maintain them, until such time as the field-flowers shall again yield a sufficient quantity. Thus, concludes Gelieu, I have preserved hives whose circumstances seemed to be desperate.

'Spiders annoy the hive much. The bees get entangled in their webs, and are not able to extricate themselves. Here cleanliness is the best protection; therefore care should be taken to sweep the webs away from the hive and its avenues as fast as they appear.

'Birds, such as the sparrow, house-lark, and swallow, eat a prodigious quantity of bees, especially in spring, when the trees are in blossom. Poultry, also, that roam about or near the water where the bees go to quench their thirst, gobble up a great many. Fowls should never be permitted in any apiary.

'Mice, especially the red mouse, or *Sorex araneus*, sometimes penetrate a hive in the winter-time, either from the entrance being left too wide, or by gnawing a hole for themselves in the straw. They eat the honey, and even the bees, when clustered together on the side of the hive, in which position they are unable to defend themselves, and scarcely even see the enemy. The most effectual preventive against rats and mice is to place the hive on stands with projecting ledges, and in such a position that they cannot reach it.

'Wasps are also reckoned among the numerous enemies of bees. I have, however, seldom seen a hive destroyed by wasps; although they are larger, stronger, and armed with a formidable sting, and an impenetrable cuirass, they seldom dare enter a well-stocked hive. Once attacked, they soon fall beneath the united efforts of these brave citizens, who sacrifice themselves to defend the place of their nativity. Wasps only appear in great numbers when the fruit is ripening, and then they range unceasingly round the hives, and enter the weak ones, or those of which the too spacious lodging bears no proportion to the number of its inhabitants. There are three ways of providing against the attacks of wasps: the first is, to unite weak hives by doubling or tripling the population, thereby enabling them to defend themselves; the second is, to contract the entrances, as soon as swarming time is over, after the massacre of the drones; and the third is, to destroy with assiduity all the nests of wasps that can be discovered in the neighbourhood.

'Bees are subject also to a peculiar species of *pediculus*, called the bee-louse. Hives that have swarmed more than once, and such as contain but little honey, are most exposed to those troublesome vermin. The hives in this case should be cleared at the furthest once every week, and the stools on which they stand every morning; for the latter are likely to harbour the larvæ and moths, or other insects, as well as the hive. But these obnoxious creatures cannot be entirely extirpated without taking away the infected hive, removing the bees, and cleaning it, before it is restored to the former station. The lice are of a slender shape, or filiform, and of a ferruginous colour, and may be destroyed by strewing tobacco over the bees.

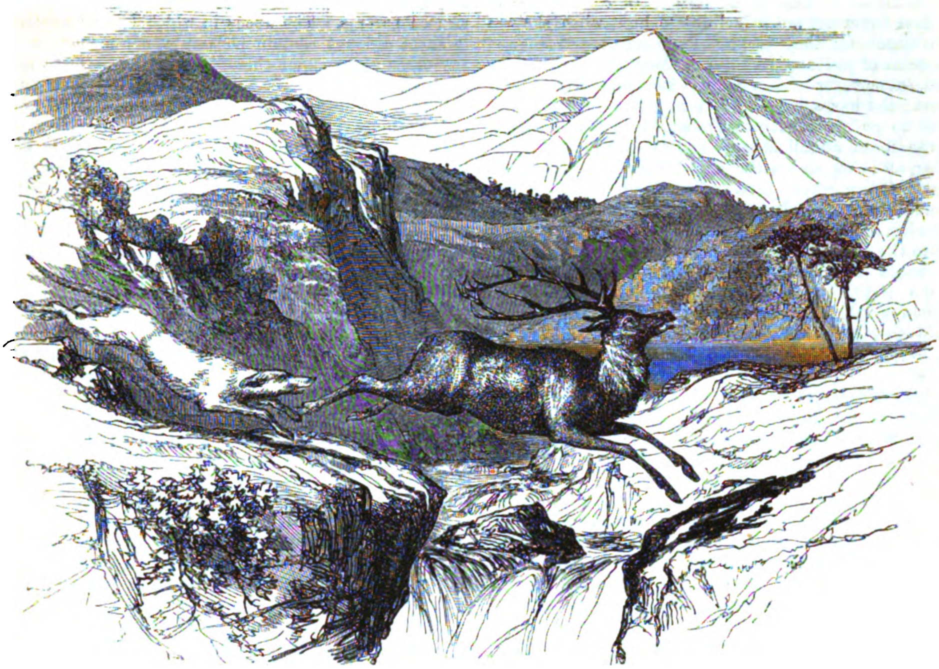
'The bees are continually fighting between themselves, and robbing each other: avarice, not necessity, leads them to do so, it being almost always the strongest and best provisioned hives that pillage the weak ones. When once a bee has been able to introduce itself into a hive, and carry away a load of honey without being arrested, it will return a hundred times the same day; and, making it known to its companions, they will then come in hordes, nor cease their pillage until there is nothing left to take. In one day, the whole of the honey will be carried off, and with a determination which one can scarcely have an idea of without seeing it. This kind of pillage is most frequent in the spring and autumn, and it is easier to prevent than to stop it; and, for this purpose, the entrance of the hives ought to be straitened in proportion to the population.'

BRITISH WILD BEES.

Besides the garden or hive bee, as already mentioned, there are various species of bees, which have never been domesticated by man, though many of them construct hives and produce honey. Of such of these wanderers of the wilds as are indigenous to Britain, the most common is the *humble*-bee (*bombus*), an insect at least double the size of the hive-bee, with a black head and body, having yellow rings crossing the latter anteriorly and superiorly, and white and black rings alternating at the posterior extremity.

On account of their peculiar habits, this and the other wild species are unfitted for domestication. Few of them survive the rigours of winter; but one, a female, that does escape, manages for a season the resuscitation of the breed. Abroad it flies in early summer, and, alone and unaided, sets laboriously to work in constructing its nest, piercing the earth or moss, as its instinct may be, and excavating a small chamber wherein to lay its eggs. It does not make wax and cells for the young. These come to maturity in the cocoons which they spin for themselves in the larva state; and when they emerge, these cocoons form stores for food. The solitary bee feeds alone its earliest progeny, but these soon multiply around it, make more cells, gather honey, and feed the increasing young. Towards the middle or latter part of September, however, the energies of the bees begin to wax fainter, and little further progress is made in adding to the colony, or in collecting honey. Cold and showery days begin, even by this time, to thin the number of the insect population, which are now seen creeping slowly, with damp and heavy wings, upon the stalks and petals of flowers, where they were formerly seen actively buzzing about in search of honey. The stores of the honey-cups have not outlasted the wants of the young unfledged bees, of which they were the proper food; and if the nests be examined now, these cups are found quite empty. The surviving bees by degrees forsake the nest and its furniture, leaving the latter as a prey to mice, beetles, or other animals. To shelter themselves for the winter, they seek out some dry bank, where they penetrate to the depth of eighteen inches or two feet, pushing up the soil behind them, and leaving no visible track by which they have descended. In these situations they are often found by labourers and others while digging; and such people are often greatly puzzled to imagine how the insect can have reached such a depth. Those who have attended to the habits of wild bees can readily fix on the spots where they take refuge.

The experiment of domesticating wild bees has been tried; and it was found that, by removing their nest cautiously in an evening, and placing it in a quiet situation, in a garden or other place where they could be observed, they went on with their works without apparent alarm or interruption. During the whole summer, they continued to prosecute their occupations with the same industry as other bees; but about September, as we have mentioned, the hive began to turn languid, and the numbers which appeared going and coming about the entrance became daily smaller. It was imagined they had taken refuge within the hive; but when this was opened, after all seemed to have ceased their labours, everything was found empty and deserted; there were neither bees nor honey; the stronger and younger insects, no doubt, having gone to make burrows for themselves in the earth, and the older ones having gradually fallen victims to the accidents of approaching winter. Our wild bees, therefore, appear to possess their brief lives but for self-enjoyment, or rather to form one of that order of beings created by the great Author of all, as if for the purpose of leaving no corner of the universe without its utmost allotment of sentient and enjoying existence.



The Chase.

THE DOG—FIELD-SPORTS.

ACCORDING to naturalists, the dog belongs to the family *Canidæ*, which includes the wolf, fox, and jackal. It is generally agreed that the different breeds of the domestic dog are merely *varieties*, and not distinct *species*. But the question as to what was the parent stock, is still undecided; some zoologists hold that the breed is derived from the wolf, others that it is a tamed jackal. Into this and other difficult questions of the natural history of the dog, we refrain from entering, and proceed to make some remarks on

EFFECTS OF TRAINING.

In no case is the fact of animal educability more strikingly demonstrated than in that of the dog. The pointer, setter, springing spaniel, and all that section of dogs, are understood to be descended from one stock—the Spanish pointer—with a slight crossing from the foxhound, for the sake of improving the speed. The original animal may be considered as a record of the primary powers, to which everything else must be regarded as an addition made by human training. Now, the original animal is only gifted by nature with a fine scent for game, and a disposition to make a momentary pause on seeing it, for the purpose of springing upon it. Man has converted this inclination to a temporary pause into a habit of making a full stop, or point, as it is termed; and the animal, instead of gratifying his destructive tendency by springing upon the game, has been trained to be contented with witnessing a vicarious execution by the gun of his master.

It is a mistake to suppose that only the spaniel tribe is capable of serving sportsmen in the capacity of pointers and setters. There are other classes of dogs which perseverance would enable, to a certain extent, to act in the same way. Gervase Markham, who wrote on sports in the sixteenth century, speaks of having seen dogs of the bastard tumbler kind adapted to act as setters, though not so well as those of the spaniel kind. Mr Blaine (*Encyclopædia of Rural Sports*) is of opinion that this power can be cultivated in most dogs. It has even been elicited in another and very different class of animals—the hog. Some years ago, Mr Toomer, gamekeeper to Sir Henry Mildmay, bethought him of teaching a pig to act as a pointer, having been struck by the scenting powers of the animal in its search for palatable roots under ground. He began by allowing a young female pig to accompany his pointers, in their breaking-lessons, to the field. Within a fortnight, to his own surprise, she was able to hunt and point partridges and rabbits. There being an abundance of these creatures near the keeper's lodge, her education advanced rapidly by frequent exercise, and in a few weeks she was able to retrieve game as well as the best pointer. *Slut*, as this extraordinary animal was called, was considered to have a more acute scent than any pointer in the charge of the keeper; and it was a kennel of the highest character. They hunted her principally on moors and heaths; and it often happened, that when left behind, she would come of her own accord and join the pointers. 'She has often stood,' says Daniel, 'a jack-snipe when all the pointers had passed it: she would back the dogs when they pointed, but the dogs refused to back her until spoke to—Toomer's dogs being all trained to make a general halt when the word was given, whether any dog pointed or not, so that she has been frequently standing in

the midst of a field of pointers. In consequence of the dogs being not much inclined to hunt when she was with them—for they dropped their sterns and shewed symptoms of jealousy—she did not very often accompany them, except for the novelty. Her pace was mostly a trot; she was seldom known to gallop, except when called to go out shooting; she would then come home off the forest at full stretch, and be as much elated as a dog at being shewn the gun. She always expressed great pleasure when game, either dead or living, was placed before her. She has frequently stood a single partridge at forty yards' distance, her nose in a direct line to the bird; after standing some considerable time, she would drop like a setter, still keeping her nose in the right direction, and would continue in that position until the game moved: if it took wing, she would come up to the place, and draw slowly after it; and when the bird dropped, she would stand it as before.'

These facts, together with what common observation presents to us in domesticated parrots, black-birds, ravens, magpies, monkeys, &c., place the educability of animals upon a basis, in our opinion, not to be shaken. But the most wonderful thing, and the most convincing part of the proof, remains in the fact of the transmission of *acquired qualities* by animals to progeny. The habit which education has conferred upon the pointer appears in his puppy, which may be seen earnestly standing at chickens and pigeons in a farmyard, before he has ever accompanied his seniors to the field, or received the least instruction. Here only the object is amiss; the act itself is perfect. As may be readily supposed, the puppy of a race of English pointers can be trained to the whole business of the field in one-tenth of the time which the most experienced breaker would require to effect any improvement upon the simple instinct of *the pause* in an original Spanish spaniel. On the subject of the hereditary transmission of acquired qualities by animals, we have some curious information from the venerable naturalist, Mr T. A. Knight, in a communication to the Royal Society in 1807. 'In all animals,' he says, 'this is observable; but in the dog it exists to a wonderful extent; and the offspring appears to inherit not only the passions and propensities, but even the resentments of the family from which it springs. I ascertained that a terrier, whose parents had been in the habit of fighting with polecats, will instantly shew every mark of anger when he first perceives the scent of that animal, though the animal itself be wholly concealed from his sight. A young spaniel brought up with the terriers shewed no marks of emotion at the scent of the polecat, but it pursued a wood-cock, the first time it saw one, with clamour and exultation: and a young pointer, which I am certain had never seen a partridge, stood trembling with anxiety, its eyes fixed and its muscles rigid when conducted into the midst of a covey of those birds. Yet each of those dogs are mere varieties of the same species, and to that species none of these habits are given by nature. The peculiarities of character can therefore be traced to no other source than the acquired habits of the parents, which are inherited by the offspring, and become what I call *instinctive hereditary propensities*.'

It appears from another communication made by Mr Knight to the same society in 1837, that he had then been pursuing investigations on this subject for nearly sixty years. He proceeds in that communication to give a general account of his investigations:—'At the period,' he says, 'at which my experiments commenced, well-bred and well-taught springing spaniels were abundant, and I readily obtained possession of as many as I wanted. I had at first no other object than that of obtaining dogs of great excellence; but within a very short time, some facts came under my observation which very strongly arrested my attention. In several instances, young and wholly inexperienced dogs appeared very nearly as expert in finding wood-cocks as their experienced parents. The woods in which I was accustomed to shoot did not contain pheasants, nor much game of any other kind, and I therefore resolved never to shoot at anything except wood-cocks, conceiving that by so doing the hereditary propensities above mentioned would become more obvious and decided in the young and untaught animals; and I had the satisfaction, in more than one instance, to see some of these find as many wood-cocks, and give tongue as correctly, as the best of my older dogs.

'Wood-cocks are driven in frosty weather, as is well known, to seek their food in springs and rills of unfrozen water; and I found that my old dogs knew about as well as I did the degree of frost which would drive the wood-cocks to such places; and this knowledge proved very troublesome to me, for I could not sufficiently restrain them. I therefore left the old experienced dogs at home, and took only the wholly inexperienced young dogs; but, to my astonishment, some of these, in several instances, confined themselves as closely to the unfrozen grounds as their parents would have done. When I first observed this, I suspected that wood-cocks might have been upon the unfrozen ground during the preceding night; but I could not discover—as I think I should have done had this been the case—any traces of their having been there; and as I could not do so, I was led to conclude that the young dogs were guided by feelings and propensities similar to those of their parents.

'The subjects of my observation in these cases were all the offspring of well-instructed parents, of five or six years old or more; and I thought it not improbable that instinctive hereditary propensities might be stronger in these than in the offspring of very young and inexperienced parents. Experience proved this opinion to be well-founded, and led me to believe that these propensities might be made to cease to exist, and others to be given; and that the same breed of dogs which displayed so strongly a hereditary disposition to hunt after wood-cocks, might be made ultimately to display a similar propensity to hunt after truffles; and it may, I think, be reasonably doubted whether any dog, having the habits and propensities of the springing spaniel, would ever have been known, if the art of shooting birds on the wing had not been acquired.'

GENERAL CHARACTERISTICS OF THE DOG.

The general form and aspect of the dog is too well known to require any description. He has six incisory or cutting teeth in both jaws; beyond which there are, on each side, both above and below, a canine tooth; and still further into the mouth are six cheek-teeth, or molars, in each side of the upper jaw. The first three are sharp and cutting, which Cuvier calls false molars. The next tooth on each side is a carnivorous tooth, furnished with two cutting lobes, beyond which the other two teeth on each side are flat. There are seven cheek-teeth, on both sides, in the under jaw; four of these are false molars, a carnivorous tooth, with the posterior part flat, and behind it two tuberculous teeth. The muzzle is elongated, subject to great variety of length in different varieties. The tongue is smooth and soft; the ears erect in the wild varieties, and in some of the tame ones, but, in the latter kinds, for the most part pendulous. The fore-feet are provided with five toes, and the hind-feet with four toes, furnished with rather longish nails, obtuse at their points, and not retractile. Occasionally a fifth toe occurs on the hind-feet, termed the *dew-claw;* this is generally removed by the sportsman when the animal is young, as its presence is calculated to impede the animal's movements. The dew-claw is regarded as a sign of degeneracy. The females are provided with both inguinal and ventral teats. The pupils of the eyes are circular.

The female goes with young sixty-three days, and

generally produces from three to five at a birth, and sometimes even twelve, which are at first blind, continuing so for from nine days to a fortnight. About the end of two months their faculties begin to develop themselves. They shed their first teeth at the end of six months, which are replaced by others that do not exfoliate. At twenty months, or two years, dogs arrive at their full vigour. The males continue to propagate for nearly their whole lives, while the female discontinues having young ones at about the age of eight or nine years.

The average age to which dogs live is about fourteen years; they frequently, however, live to sixteen, and even have been known to attain the age of twenty years. In their latter days, dogs frequently suffer greatly from decay, and various diseases. They are extremely subject to rheumatism, from their liability to exposure to rain and damp kennels. Until dogs have attained seven or eight years, their teeth are white, smooth, and acutely pointed; but after this age they become yellow-spotted, and their points assume an uneven and jagged appearance. At this time, also, the hair of the muzzle and around the eyes assumes a hoary appearance, and becomes whiter as they increase in years.

The dog is naturally carnivorous; but when domesticated, he does not refuse farinaceous food. He uses grass as a medicine; and drinks by lapping with his long flexible tongue. He does not sensibly perspire by the skin; the superfluous moisture of the body escapes at the mouth by panting, when heated, and by the extraordinary diuretic habits of the animal. The sense of smell is different in different varieties, but in all is sufficiently strong and refined to enable the dog to seek out and follow his master even amidst a crowd. His sense of hearing is also quick. He expresses anger by growling or barking, but also barks when joyful; and shews delight by the wagging of his tail. He exhibits fear by crouching and whining, howls when pained, and droops his tail under reproof. He sleeps very lightly, so as to be awakened by the slightest noise; and during his slumbers he is apt to dream, as is indicated by starting, whining, and short barks.

The most remarkable feature in the character of the dog is his attachment to man. In wild unpeopled countries, dogs are known to live in hordes, and seek their prey like other untamed animals; but brought into connection with human society, the dog leaves his own species without regret, and is only happy when belonging to a master to whom he can be faithful as a friend, servant, or companion. In this condition of domestication his ambition seems to be the desire to please; he is seen to come crouching along, to lay his force, his courage, and all his useful talents, at the feet of his master: he waits his orders, to which he pays implicit obedience: he consults his looks, and a single glance is sufficient to put him in motion: he is more faithful than even the most boasted among men: he is constant in his affections, friendly without interest, and grateful for the slightest favours: much more mindful of benefits received than injuries offered, he is not driven off by unkindness: he still continues humble, submissive, and imploring; his only hope to be serviceable, his only terror to displease: he licks the hand that has just been lifted to strike him, and at last disarms resentment by submissive perseverance.

More docile than man, as Buffon observes, more obedient than any other animal, he is not only instructed in a short time, but he also conforms to the dispositions and manners of those who command him. He takes his tone from the house he inhabits: like the rest of the domestics, he is disdainful among the great, and churlish among clowns. He knows a beggar by his clothes, by his voice, or his gestures, and forbids his approach. When at night the protection of the house is committed to his care, he seems proud of his charge; he continues a watchful sentinel; he goes his rounds, scents strangers at a distance, and gives them a warning of his being upon duty. If they attempt to break in upon his territories, he becomes more fierce, flies at them, threatens, fights, and either conquers alone, or alarms those who have most interest in coming to his assistance; however, when he has conquered, he quietly reposes upon his spoil, and abstains from abusing—thus giving at once a lesson of courage, temperance, and fidelity.

CLASSIFICATION OF VARIETIES.

Cuvier, the eminent French naturalist, formed a classification of dogs, founded on the shape of the head, and length of the jaws and muzzle. These he has separated into three great groups, as follows:—

I. MATINS.—These have a head more or less elongated; the parietal bones insensibly approaching each other, and the condyles of the lower jaw placed in a horizontal line with the upper cheek-teeth.

II. SPANIELS.—The head moderately elongated; the parietal bones do not approach each other above the temples, but diverge and swell out, so as to enlarge the forehead and cavity of the brain. In this group are included all the varieties of dogs which are of the greatest utility to man, and also the most intelligent.

III. DOGUES.—The muzzle more or less shortened; the skull high; the frontal sinuses considerable; the condyle of the lower jaw extending above the line of the upper cheek-teeth. The cranium is smaller in this group than in the two previous, owing to the peculiar formation of the head.

These three groups have, for convenience, been further subdivided into nine sections, which we shall now treat *seriatim*—noticing the different breeds or varieties which have been ranked under each.

I.—Dogs with Lengthened Heads.

SECTION 1.—Half-reclaimed dogs, which hunt in packs.

The *Dingo*, or *Australian Dog*.—The head of this dog is not unlike that of a wolf, on which account Bewick calls it the New South Wales wolf. The muzzle is long and pointed, with short erect ears. He is two feet six inches in length, and about two feet in height. His fur is composed of a mixture of silky and woolly hairs, and is of a deep yellowish-brown colour; and his tail is long and bushy, resembling that of a fox, but generally carried curled over his haunch, and not pendent. The dingo, though naturally ferocious, is easily rendered tolerably tame; and in this state many specimens are now brought to this country. They are not to be trusted, however; and the moment they escape from confinement, all their natural blood-thirsty propensities return. We knew one which, after two years' domestication, happened to slip the chain; and in less than a week, upwards of a score of sheep were destroyed by him in the neighbourhood.

The *Dhole* is the native wild-dog of India, and bears a strong resemblance to the dingo, but without the bushy tail of that species: he is of a uniform bright-red colour. Differently from other dogs which hunt in packs, according to the account given by Captain Williamson, this species always hunts mute, and only utters a soft whispering sound when in high chase, and near his prey. The dhole is exceedingly swift of foot, and soon overtakes most animals which are the objects of his pursuit. It is said they are exceedingly fond of the flesh of the tiger, and that, in consequence, this animal is prevented from propagating to that extent which would soon overrun and lay waste all the countries which it inhabits. This predilection is confirmed by Bishop Heber, who states, upon the authority of the peasants of Khayssa, which borders the frontiers of China, that a tiger is often killed and torn to pieces by the wild dogs, which give tongue like foxhounds or harriers. It is in the unfrequented wilds of the western frontiers of India that the dhole takes up his abode,

lurking amongst the extensive jungles which cover mighty tracts of that territory.

The *Pariah* is the common village-dog of India. He has a small sharp head, with short pricked ears, a slender body, and particularly drawn up about the abdominal region; his chest is deep, his limbs light, and his colour is of a reddish-brown. The native Indians use the pariahs in hunting the tiger and wild-boar. They are very fierce, and follow their game with much avidity and determination.

The *Ekia* is the native dog of Africa, and in all likelihood sprung from the same stock as the dhole. They are said to be of various colours—as black, brown, white, and yellowish. They are eaten by the negroes, who relish them greatly. The African wild-dogs, like those of India, hunt in packs.

The *South American Dog* is not unlike the dingo, and is about the size of the springer, with short and pricked ears, like most other wild-dogs. The hair on his tail is long and bristly; he is of a brownish-gray colour on the back, with sandy-coloured spots on the legs and flanks. In general aspect he greatly resembles the wolf, but is much smaller in size. There is another South American dog called the Alco, of which there are two varieties. The head of the alco is very small, and the ears pendulous, thus differing from almost all other wild-dogs. The back is somewhat curved, and the tail rather short. It is said that the Spaniards found this dog among the natives on the first discovery of America. Herrere says that Columbus found in America many dogs which did not bark. But there is reason to suppose that whatever may have been the original types of the South American dogs, they have been greatly altered by intermixture with the descendants of those introduced at the conquest by the Spaniards.

The *North American Dog.*—We have no very distinct account of this variety, but it is said to resemble the dingo in its pricked ears and general conformation. It is remarkable for the acuteness of its scent, and very expert in the detection of its prey, or animals which it may be trained to pursue.

SECTION 2.—Domesticated dogs, which hunt in packs or singly, principally by the eye, although sometimes by the scent.

The *Irish Greyhound* ranks among the noblest of the canine race: his mien is striking, full of dignity, and his conformation beautiful. In his general shape he bears a strong resemblance to the common greyhound, but is much taller, and more robust. His use in early times was to free the country of wolves and wild-boars, which abounded in England and Ireland; hence he is sometimes termed the 'Irish wolf-dog.' The hair is rough and shaggy, and the colour of these dogs is fawn or pale cinnamon. The Marquis of Sligo is said to have had some of this breed (?), which were of various colours: some were brown and white, and others black and white. The ordinary height of the Irish greyhound is about three feet, although they have been known to reach four feet. Goldsmith, who had seen several of this breed, says they were about four feet high, and as tall as a calf of a year old. The *true* Irish wolf-dog is now extremely rare, if not altogether extinct.

The *Albanian Dog* is about the size of a full-sized mastiff. His hair is very fine and close-set, and of a silky texture, variously clouded with brown; his tail is long and bushy, and carried like that of a Newfoundland dog; his muzzle is pointed, and rather long; his legs are strong and muscular, which fit him well for hunting the wild-boar, in which sport he was much used in ancient times; he was also used in hunting wolves, and in protecting sheepfolds from thieves.

The *French Matin* has an elongated head, and flat above; his ears are erect, and slightly pendulous towards the tips; the hair of a yellowish fawn-colour, with darker, oblique, and parallel indistinct rays traversing the whole of his fur. His height is about two feet, and his length three feet. He is strong, muscular, and active, and very courageous. He evinces great eagerness in hunting the wild-boar and wolf, in which sport he is frequently employed. Pennant thinks this variety is a descendant of the Irish greyhound.

The *Scottish Highland Greyhound* will either hunt in packs or singly. He is an animal of great size and strength, and at the same time very swift of foot. In size he equals, if not excels, the Irish greyhound. His head is long, and the nose sharp; his ears short, somewhat pendulous at the tips; his eyes are brilliant and very penetrating, and half concealed by the long crisped hairs which cover his face and whole body. He is remarkable for the depth of his chest, and tapers gradually towards the loins, which are of great strength, and very muscular; his back is slightly arched; his hind-quarters are powerfully formed, and his limbs strong and straight. The possession of these combined qualities particularly fits him for long endurance in the chase. His usual colour is a reddish sand-colour, mixed with white; his tail is long and shaggy, which he carries high, like the staghound, although not quite so erect. It is this noble dog which was used by the Scottish Highland chieftains in their great hunting-parties, and is supposed to have descended in regular succession from the dogs of Ossian.

The *Russian Greyhound* is nearly as large as the Irish greyhound, resembling him in shape as nearly as possible, but covered with long bushy hair. His general colour is a dark reddish-brown. He is sometimes hunted in small packs, and as frequently single, in which case he not unfrequently will kill a wolf, deer, or wild-boar, without any aid whatever. When used in coursing, he is taken to the field in slips, in the manner practised with greyhounds.

SECTION 3.—Domesticated dogs, which hunt singly, and always by the eye.

The *Gazehound* is a dog the breed of which is now lost. It was hunted in the same manner as the greyhound, and took foxes and hares by running them down. It is said by Bewick that it was employed in stag-hunting, which we think is rather doubtful, as although the stag is an animal of great speed, yet the contest between it and a dog possessing the swiftness of a greyhound would be but very unequal.

The *Greyhound* is the fleetest of all dogs, in consequence of his peculiar conformation. His head is long,

Shepherd's Dog—Scotch and Irish Greyhounds.

tapered, and shaped like that of a snake; his neck long and slender; his ears somewhat erect and pricked, slightly pendulous at their tips: the tail ought to be very

fine, curved and pointed, and the hair on it very short; the chest should be wide and deep; the belly drawn up with strong loins, and with large and prominent hip-muscles. This dog is by no means so intelligent as many other varieties, and he is, in consequence, much less susceptible of education. He has, however, very fine feelings, and seems to be much alive to caresses, which excite him to such a degree, as to produce a quick pulsation of the heart. This may be felt beating against his side with much vigour. He is one of the most elegantly formed of all the canine species.

The *Scotch Greyhound* is formed exactly like the common greyhound, and differs from it merely by being of a larger size, and in the hair being longer and wiry. The general colour is reddish-brown or sandy.

The *Italian Greyhound* is merely a miniature of the common greyhound, being only about half the size of that dog. It has a very fine coat of a silky texture, and is so tender, as to be easily injured by cold or wet. It is used only as a *pet*, being altogether valueless in other respects.

The *Turkish Greyhound* is still smaller than the Italian greyhound, being little more than half its bulk, and is entirely divested of hair, except on the tail, where it is few and scattered. Its usual colour is a blackish lead-colour. It abounds in Turkish towns, where it forms a dreadful nuisance to travellers.

II.—Head less elongated than former Division.

SECTION 4.—Pastoral dogs, or such as are employed in domestic purposes.

The *Shepherd's Dog* is covered with long, flowing, and somewhat woolly hair; his muzzle is long and pointed, and his ears erect, and slightly bent downwards at the tips; his tail is long and bushy; and the usual colour of his fur black and white, or varied with black and gray; the backs of his fore-legs have also long hairs. The peculiar and highly useful qualities of this dog seem to be rather intuitive than acquired; indeed, scarcely anything can exceed the quickness with which he is taught any lesson; and certainly no other dog has the same patient perseverance and courageous fidelity, or is at the same time possessed of greater discrimination. The labour of a shepherd, with the assistance of this faithful and intelligent animal, is comparatively an easy task; and it is hardly possible to fancy a more arduous employment than it would be, if divested of the services of the dog: for without him, how could he collect extensive flocks scattered over high and widely spread mountain-ranges? The shepherd's dog is possessed of great sagacity, gratitude, and self-denial, as is well known from innumerable anecdotes.

The *Cur*, or *Watch-dog*, differs from the shepherd's dog in being nearly smooth; he is stronger in his make, and has half-pricked ears, and his tail is rather short, and slightly feathered beneath. He is a trusty and useful servant to the farmer and grazier, and is chiefly employed in driving cattle; and being larger and stronger than the shepherd's dog, from which he is sprung, he is better qualified for the grazier and farmer. He bites with great keenness, and always makes his attack at the heels. His sagacity is very great, and he soon knows his master's fields, and watches with great assiduity the cattle which are in them. A cross between this and the true shepherd's dog has been found to be extremely useful on the sheep-runs of Australia.

The *German Dog* is a small-sized animal, with bushy turned-up tail, shaggy neck, small muzzle, and is generally of a cream-colour, but also sometimes black. His manner is brisk, and his character that of great fidelity. He is seen all over Central Germany, where he appears to be employed chiefly as a merry companion to man, and also for watching. A few specimens are beginning to be seen in England.

SECTION 5.—Water-dogs, which delight in swimming, having their feet in general semi-webbed.

The *Pomeranian*, or *Wolf-dog*, has the hair on the head, feet, and ears short; but it is long and silky on the body and tail, which last is curled up in a spiral form. His colour is white, black, gray, or sometimes yellowish; his head is long, and his muzzle pointed; his ears are short and pricked. He is possessed of intelligence nearly equal to that of the shepherd's dog, but is much less to be trusted.

The *Siberian Dog* has much the appearance of the Pomeranian dog, and is very nearly allied to him, except that he is covered with long hair, even on the head and paws. In their native country, four of these dogs are attached by pairs to a sledge, and in front of them is placed a leader, on the proper training of which much of the useful services of the others depends. These sledges are just large enough to contain one person, who directs the team with his voice, and in which he is partially assisted by a stick. The reins are fastened to the dogs' necks by a collar. Thus yoked, they have been known to drag a sledge from seventy to eighty miles in a day; and so powerful is their scent, that they contrive to keep on the beaten track by that means alone, even though it be obliterated by fallen snow.

The *Greenland Dog* is of a large size, strong in the bone, and its fur consists of long, thick-set, wool-like hair; his muzzle is sharp, and his ears short and pricked; his tail is thick, bushy, and spirally twisted. He is closely allied to the preceding variety.

The *Iceland Dog* is shorter in the hair than the above variety; his ears are pricked, but slightly bent downwards on the tips. His general colour is white, with patches of black differently disposed.

The *Esquimaux Dog.*—This highly useful variety is described by M. Desmarest as having the head shaped like that of the wolf-dog; the tail is spreading and curved, and the ears erect. The hair is thinly scattered, and consists of two sorts, the one silky, the other thick and fine, and somewhat curled, and so detached from the other that it may be pulled off in flakes from the animal. The dogs of the Esquimaux are very good-tempered and intelligent; active, swift, and enduring.

The *Hare-Indian Dog* has a narrow, elongated, and pointed muzzle; his ears are broad at the base, and pointed towards the tips, and perfectly erect; his legs are long and slender, and his tail thick, bushy, and curved slightly upwards, but by no means so decidedly curved as that of the Esquimaux dog. His body is covered with long straight hairs, the ground colour of which is white, marked with large irregular patches of grayish-black, intermingled with various shades of brown. Dr Richardson says it has neither courage nor strength for pulling down any of the larger animals. The feet of this variety are unusually large, spread, and thickly clothed with fur, in consequence of which they can run upon the snow with rapidity and ease without sinking.

The *Newfoundland Dog.*—This beautiful and intelligent dog is remarkable for the symmetry of his form and the acuteness of his understanding. He measures, from the tip of the nose to the point of the tail, six feet and a half, the length of the tail itself being two feet; from the one fore-foot to the other, over the shoulders, five feet eight inches; the girth behind the shoulders, three feet four inches; the length of his head is fourteen inches. He has webbed feet, in consequence of which he is a dexterous swimmer. His hair is long, flowing, and slightly curled, and his tail very bushy, particularly in the lower side, and he carries it in a very graceful manner. The docility of the Newfoundland dog is very great; there are innumerable most striking anecdotes of his sagacity and benevolence of disposition, particularly with reference to his saving persons from drowning. During the gale on Thursday, June 11, 1829, a vessel

was driven on the beach at Lydd; no boats could get off to the assistance of the crew, who were, however, all saved and brought ashore through the activity of a fine Newfoundland dog. The surf was rolling furiously, and eight poor fellows were crying for aid, which the spectators could not afford them, when one man directed the attention of his dog to the vessel, and the intelligent animal at once swam towards it, and the crew joyfully made fast a rope to a piece of wood, which the dog seized and swam with to his master on shore; a line of communication was thus formed, and the eight mariners rescued from a watery grave. Intelligent and sagacious as the Newfoundland dog undoubtedly is, there are certain occasions on which he is not to be trusted; and if sharply reproved or punished, is apt to resist the lash even of his master.

The *Russian Dog* is somewhat larger and stronger than the Newfoundland dog; he is a cross between that variety and the Siberian dog, and has now become a distinct race. His head is large, with his ears pendulous and rather full-sized; his tail is curled over his back; his hair is very long and shaggy, consisting of black and white patches.

The *Great Rough Water-dog* is web-footed, swims with great ease, and dives with much courage and dexterity; his hair is long and curly, and is of various colours; his legs and feet are also thickly covered with bushy hair.

The *Large Water-spaniel* is about the size of the English setter, but of a stronger make. His face is smooth, as also the front of his legs; while the rest of his body is covered with small crisped curls, usually of a dark liver-brown colour. This dog is very valuable in the sport of shooting wild-fowl.

The *Small Water-spaniel*, or *Poodle*, is a breed between the large water-dog and the springer; he is thickly covered with fine hair, all of which is in distinct small curls, more like an effort of art than of nature. It is one of the most active of dogs. Its general colour is white, and sometimes it has various black patches. It dives with much dexterity, and will leap from a very great height into the water; one has been known to leap over Old Tyne Bridge at Newcastle—a height of nearly fifty feet.

The *Shock Dog* is the smallest of the water-dog varieties, and is probably bred between the smaller spaniel or King Charles's dog and the poodle. Its hair is extremely long and flowing; so much so, that its ears and eyes are nearly concealed from view. It is kept only as a lapdog.

SECTION 6.—Fowlers, or dogs whose inclination is to chase and point birds, and hunt singly by the scent.

The *Springer* is shaped much like the English setter, but shorter in the body and legs in proportion to his size, being about two-fifths less than that dog; the hair is long and shaggy, and the ears very long and pendulous, and covered with long waved hairs. He is usually of a white colour, with patches of liver-colour or chestnut. He is, however, sometimes black, and at other times entirely of a liver-coloured brown.

The *Cocker* is about a third less than the springer, and like it in all respects. It is used as well as that variety for raising wood-cocks and snipes, in which exercise they are both very expert and hardy.

The *King Charles's Spaniel* is still less than the cocker, and distinguished by the very great length of his ears. Its hair is silky; and this, with its gentleness and small size, has rendered it a favourite pet of ladies of fashion. It was once fashionable for ladies to carry these little creatures in their arms while walking in the streets. They are sold at a high price.

The *Comforter* is another diminutive variety of this race, chiefly used as a lapdog. It is supposed to be a cross between the Maltese and King Charles's dog.

The *Maltese* and *Lion Dogs* are descendants from nearly the same stock. They are also favourites with the ladies; and are rare, but useless.

The *Alpine Spaniel*, or *Great St Bernard Dog*, exceeds other varieties of the spaniel for size and beauty. Its usual height is two feet at the shoulders; and the length from the nose to the tip of the tail is six feet. Two of these dogs are sent out from the monastery of the Great St Bernard, situated among the Alps of Switzerland, to scour the mountains during snow-storms, in search of lost or wearied travellers—the one with a warm cloak fastened to his back, and the other with a basket tied round his neck, containing a bottle with some cordial, and bread. In this employment they manifest great judgment, and seem to understand perfectly the import of their mission. They are frequently of the greatest use in meeting the travellers, who in those stormy and dangerous regions often fall victims to the inclemency of the weather. It is said that if they meet with a traveller who has sunk under the fatigue and inclemency of the blast, they will lie close to him, until by their warmth they restore heat and energy to the animation which is nearly suspended, and thus frequently will save the life of the sufferer. Should they discover a traveller to have fallen into some deep pit or fissure, whence he is unable to ascend, and if they are unable to render him any assistance, they will return to the convent and give the alarm to the monks, and then conduct them to the place where the unfortunate traveller is immured.

The *Old English Setter* is supposed to have been produced between the large water-spaniel and the Spanish pointer. The hair curled much more than in the present breed of setters, and they were very steady in the field, but not so rapid in their movements.

The *English Setter* is a mixed breed between the water-spaniel, Spanish pointer, and the springer, which has attained a very high degree of perfection as a sporting-dog. He is one of the most beautiful, lively, active, and hardy of dogs.

The *Spanish Pointer* is the stock from which the English pointer has sprung. He is one of the most stanch of all dogs used in the sports of the field, although he is considered too heavy for the present improved mode of sporting, and has now nearly become extinct in Great Britain.

The *English Pointer* was obtained by a cross of the Spanish pointer and foxhound, and is unrivalled for the

Newfoundland—Scotch Terrier—English Pointer—Cocker.

rapidity of his movements in the field, and the beauty and symmetry of his form. Since his first production, he has been improved by being recrossed with the harrier. He is subject to considerable variety in point of size as well as of colour. When well trained, and of a pure breed, he is exceedingly stanch—instances having been known where he has remained above an hour in the act of pointing.

The *Small Pointer* is a diminutive breed, being only

about two feet from the point of the nose to the tip of the tail, and scarcely a foot in height, and is a complete and beautiful miniature of the large pointer. They have proved themselves excellent sporting-dogs, but their small size renders them unfit for use in rough land.

The *Russian Pointer* is much like the Spanish pointer in shape, but his hair is long and wiry. He is valuable if well trained; but is rather obstinate and unyielding in temper.

The *Dalmatian* is a handsome animal, beautifully spotted black on a white skin. In his native country he is employed as a pointer; but imported into England, he has there lost all qualities for sporting, and is kept merely as an attendant on carriages—hence the common term 'coach-dog.' While most other dogs attach themselves to man, this one seems to care for nothing but horses. He lives by choice in the stable, and is happiest when running at the heels of the horses; even his own species he abandons in following this prevailing taste. He barks little, and is docile.

SECTION 7.—Hounds which hunt in packs by the scent.

The *English Terrier* is too well known to require any description. He is possessed of great courage, and is famous for killing all kinds of vermin, and at one time formed a useful attendant upon a pack of foxhounds, for getting into the earth when the fox had taken to his hole, and driving him out. His hair is smooth; his general colour is black, with tanned cheeks, and the insides of his legs are of the same colour. They are now to be met with of a brown, and even white colour; but these have unquestionably an admixture of some other breed in them.

The *Scotch Terrier* has short wiry hair, very rough, and is much shorter in the legs than the English terrier. His usual colour is sandy, but he is to be found black, and also gray. He bites with great keenness, and is a bold and determined dog. He will attack dogs of any size; and when he fixes on an animal, he maintains his hold with great pertinacity. He was at one time much used as an attendant upon packs of foxhounds, and forms an excellent killer of vermin. The *Skye terriers*, or terriers of the Western Isles, are longer in the body, lower in the legs, and decidedly rougher and shaggier than those of the Lowlands; indeed, they form altogether a distinct variety.

The *Talbot* is one of the primitive breeds of British dogs, and is the same which was used by the ancient Britons in the chase of the deer and other wild animals. It is now, we believe, extinct, or at least not in common use. He had a broad mouth, very deep chops, large pendulous ears, was fine-coated, and usually of a white colour. He was formerly known as 'St Hubert's breed,' and was distinct from the blood-hound, though by some confounded with that dog.

The *Blood-hound* is a powerful and sagacious animal, generally of a dark colour, with brown markings, and is endowed with a keen scent. On being led upon the footsteps of any animal or man, he will follow them up with unerring precision. This has led to the breed being employed for tracking criminals, or the unhappy victims of oppression. By the Spaniards, a breed was taken to Cuba to track the natives, and this race of animals still exists in that island. A correspondent in a newspaper thus speaks of them:—'At a period not very remote, the unfortunate negroes in the Spanish settlements were frequently torn to pieces by the Cuba blood-hounds. In fact, under the title of Chasseurs, the Spaniards maintained regular regiments of these dogs and their attendants. In pursuing or hunting the runaway negroes, the chasseur is generally accompanied by two dogs, and armed with a *couteau de chasse*, or straight sword; and we are informed that these blood-hounds, when well and properly trained, on coming up with the object of pursuit, will not kill him unless resistance is offered, but bark at and terrify him till he stops, when they crouch near him, and, by barking, give their keepers notice, who approach accordingly, and secure their prisoner.

'Dallas, in his account of the Maroon War in Jamaica, mentions an importation of these Cuba blood-hounds, in order to assist the regular troops in reducing the refractory Maroons. It may seem strange that dogs were called to the assistance of well-disciplined soldiers; but in order to elucidate the subject, it must be observed that the armed Maroons, under the conduct of various cunning leaders, particularly of Cudjoe, Smith, and Johnson, aware of their own inferiority in point of that organisation which constitutes the strength and essence of a regular army, cautiously avoided meeting their opponents on the plain; on the contrary, they retired to the impenetrable fastnesses of the woods and mountains, and by means of ambuscades, contrived so to harass the troops, that the governor of Jamaica ultimately procured a company of these dogs and their attendants from Cuba, which arrived at Jamaica under the command of Don Manuel de Sejas; and a tolerable idea of these dogs may be formed from a review which took place immediately after their arrival. General Walpole, who conducted the war against the Maroons, being anxious to review these chasseurs, left head-quarters the morning after they landed, accompanied by Colonel Skinner, and arrived in a postchaise at Seven Rivers. Notice of the general's approach having been given, the chasseurs were taken to a distance from the house, in order to advance when he arrived. The Spaniards were drawn up in a line at the end of a gentle declivity, and consisted of upwards of forty men, with their dogs in front unmuzzled, and held by cotton ropes, as it was intended to ascertain what effect would be produced on the dogs if actually engaged under a fire of the Maroons. The Spaniards, upon the word being given, fired their fusees, when the dogs pressed forward with almost ungovernable fury, amidst the shouts of their keepers, whom they dragged along with irresistible impetuosity. Some of these ferocious animals, maddened by the shout of attack, and held in check by the ropes, actually seized upon the gun-stocks in the hands of the chasseurs, and tore pieces out of them. The unfortunate Maroons, who had successfully opposed all the efforts of regular troops, were panic-struck on the arrival of the blood-hounds, and surrendered without once daring to come in contact with animals which at best could oppose but a feeble resistance to firearms.'

The *Staghound* is the largest of all the British dogs of the chase; he has a noble and dignified aspect, and possesses great sagacity and endurance in the chase: this dog is also supposed to be a direct descendant of one of our original British dogs.

The *Foxhound* has a much larger muzzle than the staghound, and his head is small in proportion to the size of his body; his ears are very long and pendulous, although less so than those of the staghound and blood-hound. Though a determined enemy of the fox, this active hound is by no means destitute of warm affections. A foxhound bitch, belonging to the Kivington Hunt, near Bolton, on the 8th of November 1792, during the chase, pupped four whelps, which she carefully covered in a rush aisle, and immediately afterwards joined the pack. In a short time after, she pupped another, which she carried in her mouth during the remainder of a hard chase of several miles, to the great astonishment of a number of spectators, after which she returned to the place where she had originally dropped the four.

The *Harrier* is used in hare-hunting, and was originally obtained by a double cross between the small beagle and southern hound. He is very eager in the pursuit of the hare. There are few instances of any of the deer tribe being hunted with success by dogs of so small a description as harriers.

The *Beagle* is the smallest of the dogs of the chase. He is possessed of a very acute sense of smelling, and

pursues the hare with unwearied steadiness; and what he wants in speed and strength, he makes up by his perseverance.

The *Otter-hound* is a cross between the large southern hound and the large rough terrier. He has a large head, with pendulous ears, and his whole fur is of a wiry texture, and rather long; his colour is either sandy or black. Otter-hunting was a favourite sport in ancient times, but is now seldom pursued.

The *Bull-terrier* is a cross between the bull-dog and the terrier, as its name implies, and has now assumed the character of a distinct breed. It is much used by gentlemen of the fancy as a fighting dog; it forms likewise a first-rate animal for the chain.

SECTION 8.—Mongrel hounds, which hunt singly either by the scent or by the eye.

The *Lurcher* is a cross between the greyhound and harrier, and recrossed with the terrier. His limbs are strong; his head less sharp than that of a greyhound; his ears are short, erect, and half pricked; and his hair coarse and wiry. He is much used by poachers, and is famous for killing rabbits, as he has a fine scent, and runs his game without giving tongue.

The *Leymmer* and the *Tumbler* are imperfectly known dogs, which are now nearly if not entirely extinct. They hunted both by the scent and eye.

The *Turnspit* is a small dog with a long body and short crooked limbs, and was much used in turning the spit before the invention of jacks. Breeds between this now useless variety of dogs and mongrel terriers and hounds, appear to form the nondescript and ugly races of animals which haunt the streets of our large towns, but whose numbers are now diminishing by the proper interference of the police.

III.—With Short Heads.

SECTION 9.—Watch-dogs, which have no propensity for hunting.

The *Mastiff* has a large flat head, and a short and blunted muzzle; his lips are full, and hanging considerably over the lower jaw; his ears, although rather small, are pendulous. He has a sullen and grave aspect, and is excellent as a watch-dog; his voice is loud and deep-toned. He is a dog of large size, and is supposed to have been produced betwixt the Irish greyhound and English bull-dog. Like the dog next mentioned, he is ferocious in disposition, and of little use when out of the chain.

The *Bull-dog* is remarkable for the depth of his chest and the strength of the whole muscles of his body. His head is large, flattened above, and his muzzle much blunted, with the under jaw projecting considerably beyond the upper one; his eyes are set far apart, and project somewhat from his head; his power of smelling is less acute than any other of the canine race, on which account he is a dangerous dog, for he has frequently been known to lay hold of his master without discriminating the difference between him and a stranger. He is the boldest and most obstinate of all dogs, and has been known to hold his adversary so determinedly that his legs have been cut off without making him desist.

Many instances have been recorded of the invincible courage of the English bull-dog, but we scarcely recollect one in which so much unconquerable spirit and tenacity of life have ever been displayed as on the following occasion:—Some years ago, a large dog of this species, from some cause that was not observed, suddenly flew at a fine cart-horse that was standing at the end of the Salthouse Dock, Liverpool, and fixing his lacerating teeth in his shoulder, defied every effort to get him off. At first he was beaten with cart-whips and sticks, with much fury; but this being unavailing, a carpenter with an adze in his hand came up and beat him with the blunt iron head of the instrument, but the dog never moved a tooth. A man then took out a large pointed clasp-knife, with which he stabbed him repeatedly in the back, loins, and ribs, but with no better success. At length one of the spectators, who appeared to have more strength of sinew and arm than the rest, squeezed the ferocious beast so tightly about the throat, that at length he turned up the white of his eyes and relaxed his jaws. The man threw him off to a distance, but the dog immediately went round the crowd, got behind the horse, and again seized him by the under part of the thigh. As no terms could now be kept with this untamable brute, he was again loosened and thrown into the dock to drown. He instantly, however, rose to the surface, when a sailor struck him a supposed deadly blow on the head with a handspike, which again sent him to the bottom. He arose once more, and was again sent down in the same manner, and this process was repeated five or six times. At length one of the bystanders, who either possessed or assumed some right of property in the dog, overcome by his amazing tenacity of life, and weary of persecution, got him out, and walked off with this prodigy of English courage, to all appearance very little the worse for the horrible punishment he had undergone. Since the very proper disuse of bull-baiting, this ferocious variety of the dog has fortunately diminished in number.

The *Pug-dog* is descended from the bull-dog, by a cross with the small Danish dog, and resembles the former so much in appearance that he may be considered as a miniature of that variety. He is a useless dog, and with generally a bad temper, has no good quality to recommend him.

GENERAL MANAGEMENT.

As formerly mentioned, dogs are very susceptible of education, and will fall into such habits as are impressed upon them by a course of training. Whatever be the peculiar variety kept in or about a dwelling-house, it is important that he be at least taught good manners; as, for example, to be silent and lie down when bidden, to refrain from leaping on the knees of persons visiting the family, and not to sit staring at meals, watching every bit that is put in the mouth. To make a dog behave properly in these and other points, he must be carefully taught when young, and for this purpose his master requires to employ a judicious mixture of severity and gentleness. He must be made fully aware that he must do as he is bid; that if he do not, he will be punished, but that if he obey, he will be rewarded. As all dogs are very tractable in such matters, they will soon learn to comprehend the meaning of a look, a sign, or a word, and will act accordingly. As very few persons take the trouble to teach domestic dogs either one line of conduct or another, we see on all occasions instances of the natural consequences of such neglect.

Breeding.

The best dogs are produced from parents not less than two years old, to which period a valuable bitch should be reserved. All who are interested in preserving the breed of their dogs should on no account suffer a cross. In every instance, let the male and female be of the true breed designed, not mixed or deteriorated. If a slight alteration of character be desirable, a cross of the English bull-dog will be found useful by giving determination. Breed always from the healthiest and best-shaped animals. Mongrel breeds are good for nothing.

Breeders of sporting-dogs require to pay marked attention to these principles. According to the author of the *Oakleigh Shooting-guide*, the theory respecting pointers is, 'that the further any dog is removed from the original Spanish pointer, the worse the dog is; and, consequently, that all attempts to cross the pointer with any other blood must necessarily deteriorate the breed. The greyhound is seldom or never crossed to give him additional fleetness, nor the hound to improve his nose;

why, then, should the pointer be crossed with dogs which, in so far as the sports of the field are concerned, scarcely inherit one quality in common with him? Attempts, however, are constantly made to improve the pointer by a cross with the blood-hound, foxhound, Newfoundland dog, or mastiff, sometimes with a view of improving his appearance, and bringing him to some fancied standard of perfection, but in reality inducing a deformity. The best pointer is the offspring of a pointer-bitch by a pointer-dog; such a one is nearly broken or trained by nature. The Spanish [or true] pointer seldom requires the whip; the hound-pointer has never enough of it.' The same writer continues—'Dogs should be constantly shot over during the season by a successful shot, and exercised during the shooting recess by some person who understands well the management of them, otherwise they will fall off in value—the half-bred ones will become unmanageable, and even the thorough-bred ones will acquire disorderly habits.'

It appears that the females are liable to receive mental impressions of the appearance of the males with which they have been in company, and that these remembrances will affect their progeny even for years afterwards. We beg to refer to Blaine's *Encyclopædia of Rural Sports*, p. 412, for some interesting information on this subject.

Whelps, at a month old, are generally deprived of their dew-claws. With some varieties it is also the custom to shorten the ears and tail, with a view of improving their appearance; but it is questionable if any breed can be improved in aspect by such treatment, and certainly no pure and well-formed variety can benefit by such mutilations. There is a prejudice of very old standing, that dogs have a worm beneath their tongue, and that the removal of this, called *worming*, deprives the animal of the power of biting should it become rabid. No worm exists; and it is doubtful if the process is of any use. That which is called a worm is merely a minute ligament or fibrous cord in the bridle beneath the tongue; and when the bridle is cut, the ligament may be drawn forward and separated at both extremities; the contraction of the ligament, on extraction, resembles the movement of a worm, and hence the origin of the term.

Feeding.

Some of the most troublesome traits in the dog's behaviour arise from mismanagement in feeding. If a dog be half-hungered, he cannot be blamed for watching the breakfast or dinner table. We advise all who indulge themselves with keeping dogs, not to leave their feeding to the chance scraps of either the kitchen or the parlour. Give the dog his own regular meals, and with food suitable to his wants or the duty he has to perform. The food should be chiefly flesh of some kind, boiled and cold; if given raw, it has a tendency to foster ferocity of disposition, and will cause the animal to be offensive in smell. No pet-dog, especially, should ever be allowed to eat raw meat. Any common pieces of flesh or tripe will answer for dog's meat. Some persons give liver, which is decidedly bad; it relaxes the bowels, and is otherwise objectionable. Besides the piece of boiled meat considered necessary, give dogs a few bones from the dinner-table; they are fond of these, and they are useful in cleaning and preserving their teeth, and keeping their bowels in order. If the dogs will take it, they should also be given a little farinaceous food, as morsels of bread or a little oatmeal porridge with milk.

The nature of the dog leads him to feed well when food is offered to his appetite, and to feed seldom. Once a day, therefore, is, in ordinary circumstances, sufficiently frequent for his meals. Present him with his allowance in the morning or forenoon, and give him no more till next day. He, however, requires to drink frequently; and it is a leading rule in keeping a dog, to have at all times a pan of clean cold water ready for his use. Change the water daily, or oftener.

For the feeding of hounds, Daniel recommends that flesh meat should be alternated with a diet of oatmeal porridge made with broth in which meat has been boiled. Greens boiled in their meat is also proper. 'A horse killed and given to the hounds whilst warm, after a very hard day, is an excellent meal; but they should not hunt till the third day after it. The bones broken are good for poor hounds, as there is great proof in them. Sheep trotters are very sweet food; and bullock's paunches may also be of service in a scarcity of horse-flesh. Hounds should be sharp-set before hunting; they run the better for it.' The same excellent authority continues to observe, that hounds should be fed once when returned from the fatigues of the chase, and again some time afterwards. 'It is the best plan to feed twice the hounds that have been out. Some hounds will feed better the second time than the first; besides, turning them out from the lodging-house refreshes them; they stretch their limbs, and the litter being shaken up, and the kennel cleaned out, they settle themselves better on the benches afterwards. At all times, after being fed, the hounds should be turned into the grass-court to empty themselves; it will not a little contribute to the cleanliness and health of the kennel.'

Lodging—Kennel Treatment.

Dogs require to be lodged in a dry situation, at a moderate temperature. The practice of keeping dogs out all night during frosty weather, or of putting them into cold coach-houses, is most inhumane and disgraceful. Those kept for watching the outside of premises should be provided with a comfortable house of wood, bedded with clean straw, and sheltered from cutting winds. A dog kept in a dwelling-house should have an appointed place, as in a lobby, for sleeping; its berth should consist of a basket, open box, or small house, according to the taste of the animal. A spaniel will not go into a dog-house; a terrier prefers it. In any case, the berth should be laid with a mat or carpet, which must be frequently washed.

Damp is seriously injurious to dogs. It produces rheumatisms, which shew themselves by lameness in the shoulders, and other disorders detrimental to their usefulness. It is therefore of great importance to build kennels in airy situations, and to keep them dry and airy. The best kennels are paved with tiles or stone, but on the floors there are raised benches, littered with straw in winter, on which the dogs repose. The straw should be daily changed, nothing being of so much consequence as cleanliness, both for the sake of general health, and preserving the powers of scent of the animals. For this latter purpose some keepers of packs of hounds have a change of rooms, one being used while the others are becoming sweet after cleaning. On this subject Daniel observes: 'The excellent sense of smelling, so peculiar to the hound, is what our sport entirely depends on; care therefore must be taken to preserve it, and the utmost cleanliness is the surest method: to keep the kennel sweet cannot be too much recommended, and is on no account to be neglected. The exactness of the master in this particular will insure that of the feeder.

'Hounds that come home lame should not be taken out the next hunting-day, since they may appear sound without being so. At the beginning of a season, the eyes of hounds are frequently injured; such hounds should not be hunted; and if their eyes continue weak, should lose a little blood. Such as have sore feet should have them well washed out with brine or pot-liquor. Hounds unable to work should be permitted to run about the house; it will be of great use to them; and such as are ill or lame ought to be turned into a kennel by themselves; there it will be more easy to give that attention both to their medicine and food which is requisite.'

Hounds which are properly disciplined are obedient in a very extraordinary degree to the orders of the

huntsman. 'To see,' says the writer of the article Hunting, in the *Encyclopædia Britannica*, 'sixty couples of hounds, animals all hungry as tigers, standing aloof in their yard, and without even hearing, much less feeling, the whip, not daring to move until the order is given to them. And what is the order given? Why, at the words "Come over, bitches," or "Come over, dogs," every hound of each individual sex comes forward, as the sex it belongs to may be called for, leaving those of the other sex in their places. Then the act of drawing them to the feeding-troughs is an exceedingly interesting sight—often, with the door wide open, having nothing to do but to call each hound by his name, which of course he answers readily to. The expression of countenance, too, at this time is well worthy of notice; and that of earnest solicitation, of entreaty, we might almost say of importunity, cannot be more forcibly displayed than in the face of a hungry hound awaiting his turn to draw. He appears absolutely to watch the lips of the huntsman, anticipating his own name.'

Health—Disease.

All dogs whatsoever, but those designed for field-sports in particular, require to be kept in what is called 'condition;' that is, neither too fat nor too lean, but the body in that hardy and active state that will enable the animal to perform its duties. If loaded with flesh or fat, it will not possess wind, or a due power of quick breathing, for any length of time in the chase. Colonel Cook observes, on what constitutes a proper condition: 'The ribs should be visible, and the flank moderately hollow, but the loins must be well filled up in a dog in perfect condition. When dogs exhibit general fulness and too much flesh, commence by physic and a regular course of exercise, which should be mild at first, but increased until it is severe. Avoid too great a privation of food, otherwise the conditioning process will be retarded.'

To keep a dog in a state of good health, he must not only be regularly fed and admitted freely to water, but be allowed plenty exercise daily in the open air, and kept in a cleanly condition. If his bowels appear relaxed, he is not in sound health; and as a preventive of this, let his food, as already said, be substantial, and consist partly of bones; let him also have access to grass; every proper kennel has a grass-yard to which the dogs can resort. In the pan of water used by house-dogs put a piece of brimstone; it slightly affects the water by lying in it, and helps to keep the animals cool.

All dogs are liable to be troubled with fleas, which they get from the ground; the skin also contracts dirt, and from that or other causes becomes offensive in smell. The remedy is cleanliness. Every lap or house dog should be washed at least once a week with soap and water. Some dogs have a great dislike to washing, but it must nevertheless be performed. After washing thoroughly, rub the animal dry with a hard cloth, and comb and brush it. If there be fleas, a small-toothed comb will remove them, and they should be killed as they appear. Wash and dry delicate dogs before the fire.

On the subject of physicking as a preventive of disease, or when there are symptoms of diseased skin, a little sulphur and antimony is recommended, mixed with the meat, or done up as a bolus or pill, and in this latter form pushed over the throat. 'Once a week or fortnight,' says Daniel, 'during the hunting-season, hounds should have one pound of sulphur given them in their meat; and when the season is over, half a pound of antimony should be added to the sulphur, and well mixed with the meat. This cools, and is doubtless of service to them.'

The *Mange* is a cutaneous disease in dogs, very closely resembling itch in the human species, but more inveterate, and is hereditary as well as contagious. Mr Blaine, in his *Encyclopædia of Rural Sports*, thus speaks of this nauseous complaint: 'Of all the causes which beget mange—and they are not few—the acrid effluvium from their own secretions is the most common; when it is generated by numbers, particularly when it is confined within a limited space, it is sure to appear. Close confinement of any dog will commonly produce it, and most certainly so if it be at the same time fed on salt provisions; thus there are few dogs on shipboard that do not contract it, except such as are allowed full liberty of the deck. Food too nutritive in quality, and too considerable in quantity, is productive of mange; and, on the contrary, food in a great measure withheld, or being very poor in quality, is equally a parent of the disease.' The same authority gives several recipes of medicine to be employed; the leading are—powdered sulphur, four ounces; muriate of ammonia (sal-ammoniac) powdered, half an ounce; aloes powdered, one drachm; Venice turpentine, half an ounce; lard or other fatty matter, six ounces: the whole to be mixed and administered in boluses. In all bad cases, however, we should recommend no one to attempt doctoring his dog, but to apply to a regular practitioner.

Distemper.—This disease is most common among dogs which are much kept in the house and subjected to artificial treatment. The disorder is epidemical, affects the constitution, and is very difficult of removal. It is now considered to be typhus fever, and should be treated on the same principles as that disease in the human subject. W. H. Scott, in his work on *British Field-sports*, thus describes the symptoms of distemper in a young dog: 'Sudden loss of usual spirit, activity, and appetite; drowsiness, dulness of the eyes, and lying at length with the nose to the ground; coldness of the extremities, ears, and legs, and heat of the head and body; sudden emaciation, and excessive weakness, particularly in the hinder quarters, which begin to sink and drag after the animal; an apparent tendency to evacuate from the bowels, a little at a time; sometimes vomiting; eyes and nose often, but not always, affected with a catarrhal discharge. In an advanced stage of the distemper, such symptoms will occur as spasmodic and convulsive twitchings, the nervous and muscular systems being materially affected; giddiness and turning round, foaming at the mouth, and fits. The disease is then often taken for incipient madness, into which it might not improbably degenerate.' The same authority adds: 'I have found daily mild doses of from two to three grains of calomel alone, lapped by the animal in milk, continued for four or five days, with intermissions when necessary, fully sufficient to carry it safely through the disease, even when the fever has been very high. James's powder has, however, always proved the most certain remedy.' A tea-spoonful of sulphur given weekly in milk, from the age of three to twelve months, renders the disease very mild, and has been found of the greatest service by those who have tried this simple plan. To aid recovery, nourishing diet should be given. In cases of severity, consult the veterinary surgeon.

Rabies, or *canine madness*, is the most fatal malady to which dogs are subject, and for which, so far as we have heard, there is no certain cure. Blaine considers that rabies is never produced spontaneously in dogs or any other animals, but is invariably the effect of inoculation by a bite from a dog already mad. But as the disease must have commenced spontaneously in some dog at first, we do not understand why it may not do so again; in short, the doctrine, in the exclusive form in which it is put, seems untenable. Rabies is little known in hot or cold countries; it is common chiefly in temperate regions, but shews itself principally in summer, when it may be supposed to be excited by a feverish condition of body.

The leading symptom of the rabid state is an apparent discomfort and unsettledness of purpose, with a desire to gnaw and eat anything within reach, as straw, wood, coal, or any other rubbish; as the disease advances, the

animal snaps and bites at everybody, or any animal near it. This is, however, no effect of bad temper; the dog has no wish to go out of his way to bite; he is under the influence of a derangement which makes him catch only at what is near. Like the unnatural appetite he possesses, the snapping propensity may also partly arise from the irritated state of the stomach and intestines, both of which are greatly inflamed. The throat is likewise livid; and by a constriction of parts, soon prevents the animal from swallowing. *Hydrophobia* is the name of a human disease produced by the bite of a dog affected with rabies. In it the dread of water is the most marked symptom, whilst in rabies there is a decided desire for water. In the later stages of the disease paralysis ensues, and from the fourth to the seventh day the dog expires. It is humanity to shoot the animal before this final catastrophe.

With respect to the production of rabies in the human species, there have been some very grave doubts. An idea has been started, and supported with considerable plausibility of argument by certain medical practitioners, that hydrophobia in the human being is merely a nervous affection, very much, if not almost altogether, arising from the influence of the imagination; the person bit fancies he is going mad, and mad he becomes. It is very desirable that the medical world should investigate and arrive at some determinate conclusion respecting this remarkable doctrine; meanwhile, till the matter is settled one way or other, we must speak of rabies in the human subject as a real disease, against which every reasonable precaution should be adopted. On being bit, it is always safe to wash the wound immediately, and have the parts burnt with a hot iron, or cut out. In every case let a skilled surgeon be immediately consulted—one who will not hesitate to act with promptitude and decision.

Many cures have been mentioned for the bite of a mad dog. We shall notice a few. The following, according to Blaine, is the famous Herefordshire cure, commonly called *Webb's drink*:—'Take the fresh leaves of the box-tree, two ounces; of the fresh leaves of rue, two ounces; of sage, half an ounce; chop these finely, and after boiling them in a pint of water to half a pint, strain and press out the liquor; beat them in a mortar, or otherwise bruise them thoroughly, and boil them again in a pint of new milk, until the quantity decreases to half a pint, which press out as before. After this, mix both the boiled liquors, which will make three doses for a human subject. Double this quantity will form three doses for a horse or cow; two-thirds of it is sufficient for a large dog, calf, sheep, or hog; half the quantity is required for a middle-sized dog; and one-third for a smaller one. These three doses are said to be sufficient; and one of them is directed to be given every morning fasting.' Blaine has not much confidence in this remedy, but allows it is worth trying. Mr Murray, known as a lecturer on chemistry, mentions, in a letter to a newspaper, the following remedy:—'Let a mixture of two parts of nitric and one part of muriatic acid, both by measure (evolving chlorine in a concentrated form) be applied to the wound as soon as possible, and more than once.' He adds that he has found this a preventive. M. Buisson, a Parisian physician, declares that madness from the bite of a rabid dog may be thoroughly cured by fumigating the patient in a hot vapour-bath, and afterwards keeping up the copious perspiration in bed; this he recommends to be done for several successive nights.*

FIELD-SPORTS.

Conducted on principles of moderation, humanity, and fair-play, the sports of the field may be said to be those exhilarating and healthful pursuits by which the tribes of wild animals are made subservient to man's use, or removed from a sphere in which they are inconvenient and unsuitable. In taking amusement from such sports, it is the glory of the true English gentleman to avoid every proceeding which can give unnecessary pain to the animals over which he claims dominion, and to discountenance by every means in his power such odious abuses of sport as baiting, worrying at the stake, or any other method of protracting the death of the creatures who have the misfortune to be objects of the chase. Our limited space will permit us to notice only the leading field-sports of Britain in past and present times.

FALCONRY.

Falconry was the favourite field-sport of the middle ages, as shooting with the gun is the predominant one of the present day. It appears, in this country, to have declined and gone out of use in the seventeenth century, in consequence of the gun having then become, by the addition of the lock and flint, a much more ready means of bringing down game than the use of hawks had ever been. Falconry, while it existed, was the peculiar sport of kings, and princes, and nobles, many of whom were painted in life with their hawks seated on the wrist, and were sculptured on their tombs after death with the same creature placed at their feet; thus marking the special regard in which they held the animal which was the means of giving them so much amusement.

The sport, we need scarcely remark, was founded on the natural instinct of the rapacious order of the feathered creation, as the chase may be said to be founded on the instinct of the dog to pursue the hare, fox, and other animals. The rapacious order of birds—of which the eagle, falcon, and owl are the three principal types—are formed in such a way as evidently fits them for pursuing, seizing, and destroying the smaller birds; a part in creation which at first sight appears to involve much cruelty, but which has been clearly shewn to be intended to save rather than to produce pain, and to be indispensable to a system of things in which one leading feature is, that there shall always be as many living creatures as can possibly be supported. The falcon family were alone employed for purposes of sport, as alone possessing the required docility; and of this family two or three species were more frequently used than any other. Of those possessing long wings, the falcon proper and the gyrfalcon; and of the short-winged, the goshawk and sparrow-hawk, seem to have been the favourite kinds. Species called the hobby, the kestrel, the merlin, and buzzard, were the next in request. The female, which is in all the varieties of this tribe considerably larger than the male, was alone employed in sport, and the common names of all the species apply to that sex, the male having usually some distinctive appellation: thus the male of the gyrfalcon was called the *jerkin;* of the falcon proper, the *tierce gentle;* of the goshawk, the *tiercel;* and of the sparrow-hawk, the *musket.*

These birds naturally choose retired habitations. The falcon, in particular, builds her nest amongst cliffs in wild and unpeopled regions. In order to fit birds for the sport of falconry, it was necessary to take them from the nest at a very early stage of their existence (then technically called *eyasses*), or to insnare them in their more mature age, and then train them for the purpose. A falcon in its natural state was said to be a *haggard.* The first step in training the falcon was to *man* it, or accustom it to the presence of human beings. Feeding was the grand source of the power which its keeper acquired over it. When it did as required, it was fed, and thus taught to know that it had done right, and not otherwise. If extremely refractory, a stream of cold water was directed at its head, as an admonition that

* See an account of Buisson's proceedings in *Chambers's Edinburgh Journal*, No. 257, old series.

nothing was to be gained by such conduct. From the very first, the animal was accoutred with certain paraphernalia, the *names* of which at least must be familiar to most readers. First, its head was covered by a leathern *hood*, fitting close all round, so as to shut up its eyes, and calculated, by a slit behind, to be readily slipped on and off. On the top of the hood there was a tuft of feathers, which usually has a graceful effect in the old pictures representing ladies or gentlemen travelling with their hawks upon the wrist. Leathern straps, called *jesses*, a few inches in length, were fitted to the legs of the bird by a button slipping through a slit or loop. Close beside the end attached to each leg was a small spherical *bell*, like that of a child's rattle, and composed of silver, for clearness of sound, the one being in some nice instances made a semitone higher than the other. The other ends of the jesses were furnished each with a ring, which could be readily fitted upon the swivel designed to connect them both with the *leash*, a long slender strap, sometimes prolonged by a *creance*, or common cord, and designed as a tether by which to restrain the animal, at the same time that it should be allowed considerable room for free motion. Two great objects in training were to teach the bird to fly at its proper game, and to habituate it to come back to the hand of its master, after on any occasion having been let free in pursuit of its prey. For the first of these ends, in the case of long-winged birds, an implement termed the *lure* was used. It consisted either of a stick or of a cord, on the end of which were fixed pieces of flesh, with a bunch of the feathers of the prey which it was designed that the bird should fly at, or perhaps an actual resemblance of the prey in its entire form. The falcon being set loose by one man, another stood at a distance waving the lure around his head, thus tempting the animal to advance and strike at it. A whistle was the implement used to *reclaim* or bring back the hawk. When a hawk was to be kept on the hand, strong gloves were worn for protection from its talons. It may here be remarked, that the training of falcons was altogether a most laborious business, and that trained birds were accordingly to be purchased only at a high price. At the beginning of the seventeenth century, a trained goshawk and tiercel brought 100 marks, and it was considered a favour to part with them. The extreme labour attending the training of the animals must have been sufficient in early times to confine the sport to persons of birth and fortune, if there were no other cause; and it must also have conduced to the rapid decline and extinction of the sport, after a ready means of killing wild-fowl by the gun became attainable.

The sport, after being long given up, was revived in England some years ago by the Duke of St Albans, Colonel Thornton, and a few other gentlemen, chiefly through the influence of a taste for whatever is elegant and romantic in the usages of our forefathers. It is said to be a gallant and goodly sight, when a cavalcade of well-mounted English ladies and gentlemen rides forth on a clear sunshiny day to pursue this sport, attended by their falconers, each with his hawk on his wrist. In the present day, as of yore, various kinds of feathered game are flown at. Heron-hawking is, we believe, in greatest esteem. The heron, as must be generally known, is a large bird in appearance, with a long neck, long legs, and a long sharp bill, being designed to haunt marshes and pools, and feed upon whatever fish it can find therein. It is, however, a light unsubstantial bird, with nothing to protect it from enemies but its sharp bill. Herons are gregarious, and the places where they live are called heronries. These explanations will introduce the following account of heron-hawking, from Blaine's *Encyclopædia of Rural Sports*:—

'The daily visitations of the heron to its feeding-places are watched by the falconers, who station themselves to the leeward or down wind of the heronry, so that the heron, on its return, must fly against the breeze, which gives a great advantage to its enemy. As soon as one is discovered on the return, a cast of falcons is let loose, who, catching sight of the quarry, rise in pursuit. The heron, instinctively aware that its life is at stake, prepares for the fray by disgorging the contents of its stomach to lighten the weight of the body. The coursing falcons ascend the airy vault in spiral gyrations, by which the atmospheric resistance to their flight is lessened. These circlings, it has been observed, have frequently the curious effect of presenting the three birds as flying in different directions; whereas the real intentions of the two hawks are steadily directed to one point, which is that of contact with the heron, whose entire efforts are as steadily engaged in avoiding it. To effect this, the affrighted heron strenuously endeavours to rise above the hawks, who, however, by the superior power of wing, commonly succeed in getting the upper station, from which one presently makes its stoop; and happy it is for the poor heron if he can evade the blow, which he occasionally does, either by shifting his station, or by receiving the falcon on his sharp bill, which instantly transfixes it. This danger is, however, denied on authority, but we feel assured that it does occur. The second hawk, if the first fails, stoops in his turn; but the meditated blow of this also is frequently evaded like the former. The trio then still rising higher and higher, the sight becomes interesting in the extreme, and the spectators are scarcely less agitated than the feathered warriors above. At length another stoop takes place, and the fatal seizure is made by one hawk, while the other *binds* to his fellow, and all three quickly descend together, but not with a dangerous rapidity, as their powers of inflation and the action of their wings break the fall. It is now that the mounted horsemen make the best of their way to the assistance of their falcons, and their first efforts must be directed to secure the head of the heron, that the sharp beak may not take effect on one or both of them.'

Pheasants are objects of this sport, but not to a great extent, on account of the inconvenience presented by the silvan ground in which the sport must be practised. Partridge-hawking is found to be a more convenient sport. To quote the same authority: 'The scene of practice is commonly on large fields or open tracts of country, where the horsemen and company generally can beat in line, and the attendant falconer or master, being well mounted, can ride forward, and be ready to receive the quarry. Either pointers or spaniels are necessary, or both. The partridge being flushed, the hawk will stoop with astonishing rapidity, and seize on it; at which time neither horses, dogs, nor company should press forward: on the contrary, they should permit the falconer only to advance, who, approaching the hawk with caution, must walk quietly round her, when, gently kneeling down with his arm extended, as though in the act of feeding the hawk, he should lay hold of the partridge, and at the same time place the hawk on his fist. This done, restore the hood, and reward the hawk with the head of the quarry; and if she be not intended to be flown again, let her be fed immediately.

'A somewhat different method of partridge-hawking is practised in the latter part of the season, when the country is very bare, and when the partridges are often very wild, and lie indifferently even to the dog. In such cases it is recommended that the company "draw up in line at fifty or sixty yards' distance from each other, and gallop across the plain with a hawk upon wing," the falconer being in the centre of the line, that he may regulate the pace by the situation of the hawk. Sir John Sebright informs us, that this method of partridge-hawking has afforded him more sport than any other, and that when the face of the country was so bare, and the birds so wild, as to make it impossible to approach them in the usual way.

'Brook-hawking, as it is often termed, was much in vogue formerly. The practice was not, however, confined to brooks, but extended to rivers, sea-shores, moors, and ponds. It engaged, according to Blome, "the ger-falcon, the haggard-falcon, the jerkin, and the tassel gentle." Water-fowl of every description were made prey of; but some particular objects, according with the training of the falcons, were particularly sought for. Dogs were employed to rouse the fowl, being led on by men who traversed the water's edge; while horsemen, with the hawks on their fists, were at hand to *cast off* one or more, according to the nature of the game. A heron or mallard would require two, while a widgeon or a teal (being small) would probably engage only one.'

DEER-HUNTING.

Deer-hunting was another principal amusement of past times, but has now been abandoned in the form in which it used to be conducted. The species of animals chiefly hunted in England was the fallow-deer, a beautiful creature with stately horns and antlers, and of great speed in running. Fallow-deer are now closed up in parks, at least in Britain. The stag, red deer, or hart, whose female is called the hind, differs in size and in horns from the fallow-deer. He is much larger, and his horns are round, whereas in the fallow species they are broad and palmated. Red deer are now, we believe, almost the only objects of field-sport in this country, and principally in the Highlands of Scotland, where they still exist in considerable numbers. Hounds, however, as in the chase in former ages, are now seldom or never employed—the hunter depending on his gun and his skill in approaching the animal noiselessly. This, which is called *deer-stalking*, is a sport requiring a vast deal of tact, knowledge of the animal's habits, and patience, as whole days are occasionally taken up in stealthily watching an opportunity for a shot. Such is the power of sight, scent, and hearing, that to approach unperceived on a plain is impossible. They must be approached down the wind, and from behind thickets or hillocks. A telescope is required in these difficult manœuvres. When it is impracticable to reach them in this artful manner, attendants drive them into gorges among the mountains, and the sportsman singles out an object for his rifle as it passes his concealed station. A lively work on deer-stalking has been written by Mr Scrope, to which we beg to refer those who are interested in the subject; and some very graphic pictures may also be found in Mr St John's attractive volume on *The Wild Sports and Natural History of the Highlands.*

FOX-HUNTING.

The variety of fox most common in Britain is called the *cur fox*, which is of a brown colour, with generally some white on the breast and belly, and a light tip to the long bushy tail. Foxes go to *clicket* in winter, and cubs are produced in the latter end of March; they breed but once a year, and have from three to eight young ones at a time. In his nature the fox is playful, but rapacious in his appetite, and his predominating characteristic is great craftiness. He usually fixes his abode on the border of a wood, at no great distance from a farmhouse or village; he listens to the crowing of the cocks and the cries of the poultry; he scents them, and chooses the time of his attack with judgment; he conceals his road as well as his design; he slips forward with caution, sometimes even trailing his body, and seldom makes a fruitless expedition. He plans similar encroachments on the nests of birds, rabbit-warrens, &c.; and, in short, is so destructive to poultry, game, and even young lambs, that it is absolutely necessary to take and kill him.

Fox-hunting on a proper scale requires to be conducted with the class of active horses termed hunters, a pack of foxhounds to scent and run down the prey, and terriers to turn the animal from his hole, should he take to earth. A pack of hounds varies from twenty to thirty couples; but besides these, some hounds are always left undrafted into the field. The cost of a well-bred pack is reckoned at from £1000 to £1200, and the annual expense of its keep and management about as much. The huntsman, as the grand leader of the chase, is a functionary of no small importance; he is assisted by two whippers-in, who bring up and take charge of the hounds.

The fox being an early riser, and his scent lying best on the damp grass, he is hunted in early morning; and the first business on taking the field is to ride to and draw cover—that is, bring out the fox from his retreat. At the first sight, the view halloo is given by the huntsman, and all follow the sweeping track of the hounds. It is a rule in hunting never to get before the dogs, or to throw them out any way by a false signal; on the contrary, the great art is to keep them to the scent, and to aid their search. The run is considered the exhilarating part of the sport, and consists of a rapid chase through a broken or rough country, with the hounds in full cry. Then is the ardour of the chase shewn; and it continues till the fox, by some clever manœuvre—such as tracking up a brook—throws the hounds off the scent, and the party is brought to check. The scent and track of the animal being again found, off all go once more in pursuit, but with generally frequent doubts of the result. 'See,' says Beckford, in his enthusiastic style, 'where the hounds bend towards yonder furze brake! I wish he may have stopped there. Mind that old hound; how he dashes o'er the furze! I think he winds him! Hark! they halloo! Ay, there he goes! It is nearly over with him! Had the hounds caught view he must have died! He will hardly reach the cover. See how they gain upon him at every stroke! It is an admirable race; yet the cover saves him. Now be quiet, and he cannot escape us; we have the wind of the hounds, and cannot be better placed. How short he runs! He is now in the strongest part of the cover! What a crash! Every hound is in, and every hound is running for him! That was a quick turn! Again, another! He's put to his last shifts! Now mischief is at his heels, and death is not far off! Ha! they stop all at once: all silent, and yet no earth is open! Listen! Now they are at him again! Did you hear that hound catch him?—they overran the scent, and the fox had lain down behind him. Now, Reynard, look to yourself! How quick they all give their tongues! The terriers, too, are now yelping at him. How close *Vengeance* pursues!—how terribly she presses!—it is just up with him! What a crash they make; the whole wood resounds! That turn was very short! There!—now!—ay, now they have him! Who-hoop!' The chase is over: Reynard is no more; and his *brush* or tail being cut off as a trophy by the huntsman, his unfortunate carcass is thrown to the hounds, and in a few moments destroyed, leaving scarcely a wreck behind.

HARE-HUNTING—COURSING.

Hares are hunted in much the same manner as foxes, the chief difference being, that harriers are employed instead of hounds: both hunt by the scent. Of this branch of field-sports, the writer of the excellent article on Hunting, in the *Encyclopædia Britannica*, makes the following mention:—

'Hare-hunting claims precedence of fox-hunting in the sporting chronology of Great Britain, and we believe of all other countries, inasmuch as a hare has always been esteemed excellent eating, and a fox the rankest of carrion. We gather from Xenophon that it was practised before his day, and he wrote fully three centuries before the Christian era, both hounds and nets being then used in the pursuit. Neither can we marvel at hare-hunting being the favourite diversion

in all nations given to sporting, where the use of the horse in the field had not become common. But we will go a point further than this, and assert, that how inferior soever may be the estimation in which hunting the hare is held in comparison with hunting the fox, no animal of the chase affords so much true hunting as she does, which was the opinion of the renowned Mr Beckford.

'The difficulty of finding a hare by the eye is well known. It is an art greatly facilitated by experience, although not one person in ten who attempts it succeeds. But here we recognise the hand that furnished her with such means for her security; as, from the delicacy of her flesh, she is the prey of every carnivorous animal, and her means of defence are confined only to flight. In going to her seat or form she consults the weather, especially the wind, lying always, when she can, with her head to face it. After harvest, hares are found in all situations; in stubble-fields, hedgerows, woods, and brakes; but when the leaves fall, they prefer lying upon open ground, and particularly on a stale fallow-field; that is, one which has been some time ploughed; as likewise after frost, and towards the spring of the year. In furze or gorse, they lie so close, as to allow themselves nearly to be trodden upon, rather than quit their form. The down or upland-bred hare shews best sport; that bred in a wet marshy district the worst, although the scent from the latter may be the strongest. If a hare, when not viewed away, runs slowly at first, it is generally a sign that she is an old one, and likely to afford sport; but hares never run so well as when they do not know where they are. Thus trapped hares, turned out before hounds, almost invariably run straight on end, and generally till they can run no longer; and they generally go straight in a fog. The chase of the hare has been altered, and rendered less difficult in some degree by the improvement of the hound used in it.

'The difference in the terms used in hare-hunting and fox-hunting is comprised in a few words:—Harriers are cast off in the morning; foxhounds throw off: the hare is found by the quest or trail; the fox by the drag: the hare is on her form or seat; the fox in his kennel: the young hare is a leveret; a fox a year old is a cub: the view holloo of the hare is "Gone away;" of a fox, "Tallyho:" the hare doubles in chase; the fox heads back, or is headed: the harrier is at fault; the fox-hound at check: the hare is pricked by the foot; the fox is balled or padded: the hare squats; the fox lies down, stops, or hangs in cover: the "who-hoop" signifies the death of each.'

Hares are hunted with packs of generally twenty couples of harriers; but whatever number is employed, it is the established rule not to run in upon the hares as soon as discovered in their forms, but to allow them a little space before the dogs are set on. This space is termed 'law.' The hares also must not be pressed upon in the chase by the company; neither are the dogs, in losing scent, to be called on the right path; for this leads them to depend on the sight of the huntsman instead of their own nose. Leave the harriers pretty much to themselves.

Coursing is the chasing and taking of the hare by means of greyhounds, which hunt by the sight only. Among fox-hunters it is considered an inferior kind of sport, but many country gentlemen find in it an exhilarating recreation, and it is patronised by numerous coursing-clubs. 'There is,' says Blaine, 'even a philanthropic character about coursing almost unknown to other huntings. It may be said to offer a kind of refuge for the sporting destitute, for it holds out innocent recreation to those whose means or whose prudence will not allow them to risk either their neck after a fox, or their wealth after a racer. Here the octogenarian, at once labouring under his increased years and his decreased energies, may solace himself with an epitome of former huntings; and further, that the joys of this chase are within the reach of every state or stage of life.'

The greyhound, whose form so eminently adapts him for competing with the hare in a race, requires to be well trained in the art of turning suddenly, and determinedly pursuing his game on a new line of pursuit. His eye should be clear and quick, and his wind good, to enable him to hold out to the last. Greyhounds are delicate in their nature, and require very careful treatment; their lodging must be dry and comfortable; and when taken out in a cold morning, they must be held in leash, with jackets on, ready to let slip. In any case, they are not uncoupled or let go till the hare has been seen and started. A single pair of dogs is generally sufficient for the sport; and betting often ensues as to the *points* in the course. There are numerous rules of ancient and modern date on the subject of coursing. The following are those principally at present in use:—

The hare ought to have from seventy to one hundred yards' *law* before the dogs are slipped, except in particular localities, such as small enclosures.

The points are—a cote, or a go-by, when gained by speed; a wrench, or a turn, when effected by working; and a trip, or a kill.

A cote consists in one dog outrunning the other from the slips, and giving the hare a turn; or subsequently, when one dog, *after turning the hare himself*, and starting in the same position as his fellow, outruns him and makes his point. In either case, it counts two points.

A go-by occurs when a dog gains a clear length on his fellow in a straight run. It is scored two points, and any point subsequently made is scored in addition.

A wrench is when a hare is forced from her line from fifteen to forty-five degrees, and is half a point. A turn, for which one point is scored, is when the hare is forced more than forty-five degrees from her line. If, however, the hare wrenches or turns without being forced by her pursuers, nothing is scored.

A trip or jerk is when a dog lays hold of the hare and looses her again, and counts half a point; whilst the kill is one point, if at all meritorious.

The dog which counts most points gains the course, though in all cases the value of these must be left to the decision of the judge.

The allowances are—for a fall, for losing ground at the start, or the hare bearing decidedly to the other dog, for being ridden over, and for being unsighted through no fault of the dog; but in every case the allowance is to be deducted from the other dog's score.

The penalties are to be deducted from the score of the dog incurring them, and are levied for wilfully standing still in a course, or departing from directly pursuing the hare, or refusing to fence—in all which cases any points made subsequently by him are not to be reckoned.

SHOOTING—GROUSE—PARTRIDGES, ETC.

The leading sports with dog and gun are the shooting of grouse, partridges, and pheasants, which differ in some respects from each other. The first thing to be attended to in either case is having a good fowling-piece or gun; and the second is to know how to use and clean it. Next, the sportsman must be provided with dogs trained to point the kind of game for which they are taken to the field: to take a dog accustomed to point partridges on a grouse-shooting excursion would be improper. The gunpowder employed should be kept very dry in a metal flask, and of proper strength and purity. Patent shot is now commonly used; it is of eight sorts, each numbered, and rises from 83 pellets to 620 pellets in the ounce. Much variety of opinion exists as to the proper size of shot; No. 6 is often used on the moors at the commencement of the season, and as the grouse become wilder, No. 4 or 3 is substituted

The more tender the birds, the smaller may be the pellets or drops.

The following hints to a beginner in shooting are by Hawker and others:—'In raising the gun, let him remember that the moment it is brought up to the centre of the object, the trigger should be pulled, as the first sight is always unquestionably the best. Then send him out to practise at a card with powder till he has got steady; and afterwards load his gun occasionally with shot, but never let the time of your making this addition be known to him; and the idea of it being perhaps impossible to strike his object will remove all anxiety, and he will soon become perfectly firm and collected.

'The intermediate lesson of a few shots at small birds may be given; but this plan throughout must be adopted at game, and continued, in the first instance, till the pupil has quite divested himself of all tremor at the springing of a covey, and observed in the last, till most of his charges of shot have proved fatal to the birds. If he begins with both eyes open, he will save himself the trouble of learning to shoot so afterwards. An aim thus, from the right shoulder, comes to the same point as one taken with the left eye shut, and it is the most ready method of shooting quick. Be careful to remind him (as a beginner) to keep his gun moving, as follows:—before an object, crossing; full high for a bird rising up or flying away very low; and between the ears of hares and rabbits running straight away. All this of course in proportion to the distance; and if we consider the velocity with which a bird flies, we shall rarely err by firing, when at forty yards, at least five or six inches before it. Till the pupil is *au fait* in all this, he will find great assistance from the sight, which he should have precisely on the intended point when he fires. He will thus, by degrees, attain the art of killing his game in good style, which is to fix his eyes on the object, and fire the moment he has brought up the gun. He may then ultimately acquire the knack of killing snap shots, and bring down a November bird the moment it tops the stubble, or a rabbit popping into a furze-brake, with more certainty than he once used to shoot a young grouse in August or a partridge in September.

'Many begin with very quick shooting, and kill admirably well, but are often apt not to let their birds fly before they put up their gun, and therefore dreadfully mangle them; and, I have already observed, are not such everyday shots as those who attain their rapid execution on a slow and good principle.

'If a rival shooter—some stranger—races to get before you, push him hard for a long time, always letting him have rather the advantage, and then give him the double without his seeing you. Having done this, go quietly round—supposing you have been beating up wind—and on reaching the place where you began, work closely and steadily the whole of the ground or covert that you have both been racing over, and you will be sure to kill more game than he will, who is beating and shooting in haste, through fear of your getting up to him, and—if the wind should rise—driving the dispersed, and consequently closest-lying birds, to your beat as fast as he finds them.

'Beware of the muzzle of the gun being kept hanging downwards; when so carried, the shot is apt to force its way from the powder, especially in clean barrels. If it happens that a space of sixteen or eighteen inches is thus obtained, and the gun fired with its point below the horizon, it is ten to one but the barrel bursts. There are other perilous consequences besides those that generally accompany the disruption of a barrel; for the men, horses, and dogs are in perpetual danger of being shot when a gun is carried in the before-mentioned pendent manner.

'When a gun begins to exhibit symptoms of having done its work, the sooner a man discards it the better. An injured barrel or enfeebled lock may prove fatal to the owner or his associates. Accidents occur every day, and very lamentable consequences proceed, from a culpable neglect in retaining arms which should be declared unserviceable and disused.'

Grouse-shooting.—This favourite field-sport, as is well known, commences annually on the 12th of August, when thousands of persons adjourn to remote parts of the country to follow it, with all its toils and privations. Among the varieties of this game are numbered the cock of the wood or capercailzie; the black-cock, heath-cock, black game, or black grouse; the red grouse, moorfowl, or gor-cock; and the white grouse or ptarmigan. Moorfowl are the most common, and seem to be peculiar to Britain. They are very plentiful in the Highlands of Scotland, and by no means scarce in any of the wild, heathy, and mountainous tracts in the northern counties of England and Wales. Red grouse pair early in spring, and lay from six to ten eggs; the young brood follow the hen during the whole summer; and in winter they unite in flocks of forty or fifty. They are seldom seen in the valleys, preferring to keep the summits and sides of the hills, where they feed on mountain-berries and the like. Being generally hatched in April, if the summer has been dry, the young birds will be pretty strong on the wing and ready for the sportsman by the 12th of August.

The best weather for shooting is that which is dry, clear, and warm; wet makes them lie still on the ground. No one need attempt grouse-shooting who is of delicate health, or not well trained by previous feeding and exercise. The labour of walking over heather is most toilsome, and the danger of colds from rain or wet feet considerable. The dress ought to be very strong, without any regard to fineness; stout shoes or quarter-boots are indispensable.

The times of day best suited for grouse-shooting are the morning and evening, when the birds are in quest of food; but few are able to reach their haunts till eight o'clock, when the sport commences. 'To find the birds,' says the author of *Wild Sports of the West*, 'when satisfied with food, they leave the moor to bask in some favourite haunt, requires both patience and experience; and here the mountain-bred sportsman proves his superiority over the less practised shooter. The packs then lie closely, and occupy a small surface on some sunny brow or sheltered hollow. The best-nosed dogs will pass within a few yards and not acknowledge them; and patient hunting, with every advantage of the wind, must be employed to enable the sportsman to find grouse at this dull hour. But if close and judicious hunting be necessary, the places to be beaten are comparatively few, and the sportsman's eye readily detects the spot where the pack is sure to be discovered. He leaves the open feeding-grounds for heathery knowes and sheltered valleys; and while the uninitiated wearies his dogs in vain over the hillside, where the birds, hours before, might have been expected, the older sportsman profits by his experience, and seldom fails in discovering the dell or hillock where, in fancied security, the indolent pack is reposing.'

Our most practical authority on this exciting topic is the *Oakleigh Shooting-guide:*—'Grouse-shooters should separate and range singly; they should have no noisy attendants. In wet weather, one dog is sufficient; we advise rest from eleven till two. The flight of grouse is generally about half a mile. Their favourite haunts, when undisturbed, are those patches of ground where the young heather is most luxuriant. They avoid rocks and bare places where the heather has been recently burnt; at anyrate, they are not to be approached in such localities. It is in young heather that grouse most frequently feed. They are seldom found in the very long thick heather that clothes some part of the hills, until driven there for shelter by shooters or others. It is early in the morning and towards evening that grouse

are to be found in young heather. During the middle of the day, the shooter should range the sunny side of the hill, and avoid plains.

'No species of shooting requires the aid of good dogs more than grouse-shooting, and in no sport does so much annoyance result from the use of bad ones. The best dog perhaps for the moors is a well-bred pointer, not more than five years old, which has been well tutored—young in years, but a veteran in experience. The setter is occasionally used with success, but we prefer the pointer. The latter has unquestionably the advantage when the moors are dry, as it not unfrequently happens that they are in August. If a setter cannot find water wherein to wet his feet every half-hour, he will not be able to undergo much fatigue. Some sportsmen will hunt a couple of mute spaniels for grouse-shooting in preference to any other team of dogs. Of course, when this method is pursued, the birds are never pointed, and the shooter must ever be on the look-out, for the game is generally sprung very near to the gun.' Grouse-shooting, we may add, terminates on the 9th of December.

Partridge-shooting.—Of partridges there are two kinds, the red and gray, the latter being that which is common in this country; the plumage is of a brown and ash colour, elegantly mixed with black; the tail is short, and the figure more plump than handsome. Partridges pair about the third week of February, and sometimes, after being paired, if the weather be severe, they all gather together and form a covey, and are then said to pack. They begin to lay in six weeks after pairing. The female lays her eggs—from twelve to twenty—on the ground, scraping together a few bents and decayed leaves into any small hollow. The young birds begin to appear about the first ten days in June, and the earliest will take the wing towards the latter end of that month. In dry seasons, they are most numerous. So many are the enemies of the partridge, that it is believed never more than a half of those produced come to maturity, and yet there is in general abundance for the sportsman during the shooting-season. The affection of both parents for their young is very remarkable; they lead them out in quest of food, shelter them with their wings, and resort to many tricks to lead supposed enemies away from their broods. Turnip and corn fields are the places which partridges most delight in, especially while the corn is growing; for that is a safe retreat where they remain undisturbed. They frequent the same fields after the corn is cut down, and there feed on the dropped grains, finding a sufficient shelter under cover of the stubble. When the winter comes on, and the stubble-fields are either trodden down or ploughed up, they then retire to the upland meadows, where they lodge in the high grass; they also sometimes resort to the low coppice-woods, especially if they are contiguous to cornfields.

Partridge-shooting commences on the 1st of September, when the birds are strong, and terminates on the 1st of February. In the course of September, the short flights of the coveys, in tolerably well-preserved grounds, afford abundance of sport. In more open districts of country, where there is a wider range, partridge-shooting requires more skill, and the aid of a steady pointer or setter. In shooting either at a flight of grouse or covey of partridges, select a bird on the outside, and fire at it alone; it is only over-hasty or ill-taught sportsmen who let fly indiscriminately at the centre of a covey of birds.

Pheasant-shooting.—Pheasants are a species of birds allied to domestic fowls, and partake of some of their habits; no birds of the game-kind possess such elegant plumage, and few are so large. They breed on the ground, and, like partridges, are fond of nestling in clover; but their chief resort is shrubberies or secluded spots in plantations. The pheasant and its brood, if undisturbed, remain in the stubbles and hedgerows some time after corn-harvest; if molested, they seek the woods, and only issue thence to feed in the stubbles at morning and evening. Besides corn, the birds will live on wild-berries, or any seeds they can pick up. As the cold weather comes on, they begin to fly up at sunset into trees, where they roost during the night.

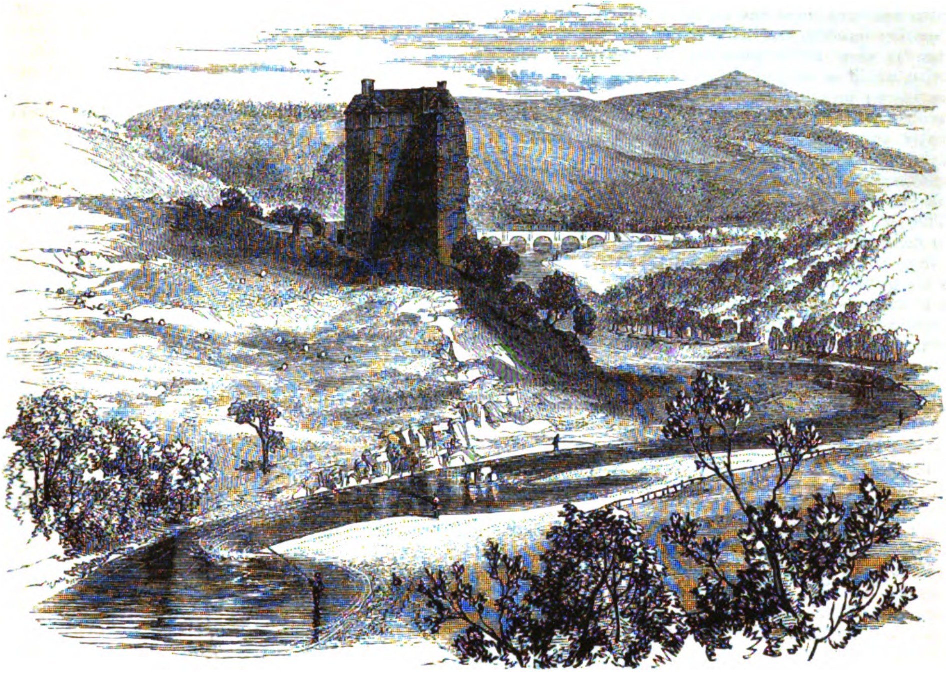
'For shooting pheasants, it often becomes necessary to start very early in the morning, as they are apt to lie during the day in high covert, where it is almost impossible to shoot them till the leaf has fallen from the trees. We can never be at a loss in knowing where to go for pheasants, as we have only to send some one the previous evening, for the last hour before sunset, to watch the different barley or oat stubbles of a woodland country, and on these will be regularly displayed the whole contents of the neighbouring coverts. It then remains to be chosen which woods are the best calculated to shoot in; and when we begin beating them, it must be remembered to draw the springs, so as to intercept the birds from the old wood. If the coverts are wet, the hedgerows will be an excellent beginning, provided we here also attend well to getting between the birds and their places of security. If pheasants, when feeding, are approached by a man, they generally run into covert; but if they see a dog, they are apt to fly up.

'There are very few old sportsmen but are aware that this is by far the most sure method of killing pheasants, or any other game, where they are tolerably plentiful in covert; and although to explore and beat several hundred acres of coppice, it becomes necessary to have a party with spaniels, yet on such expeditions we rarely hear of any one getting much game to his own share, except some sly old fellow, who has shirked from his companions to the end of the wood, where the pheasants, and particularly the cock-birds, on hearing the approach of a rabble, are all running like a retreating army, and perhaps flying in his face faster than he can load and fire.'

It is necessary, in pheasant-shooting, to use a short double-barrelled gun of wide bore, and large shot. Fire at not a greater distance than thirty yards, and only when the bird has risen clear of the bushes; aim is to be taken at the head; but if the pheasant is crossing your path, fire a little before the head, the rapid flight of the animal bringing it in contact with the shot. Towards November, this field-sport—which commences on the 2d of October, and terminates on the 1st of February—may be united with woodcock-shooting.

GAME.

Though, according to law, wild animals are no one's property, yet only certain kinds may be killed without a licence. Those protected from indiscriminate slaughter are called *game*, and are deer of every species, partridges, grouse, pheasants, wood-cocks, snipes, &c. The wild animals not reckoned game are hares, rabbits, crows, rooks, pigeons, all kinds of sea-birds, &c.; any one may kill and appropriate these, provided it be in a highway, the sea-shore, or any other public ground. Game cannot be legally taken or killed in any form without a licence procured from the competent officer of the crown, and a permission from the proprietor of the ground on which the game happens to be. To shoot or hunt without a licence is called *poaching;* to shoot or hunt with a licence, but without a permission, renders the person liable to an action for *trespass.* These game-laws are relics of ancient laws instituted by the Anglo-Saxon and Norman sovereigns for protection of the royal forests.



Angling on the Tweed.

ANGLING.

ANGLING is the art of alluring and capturing fish by means of a rod, line, and baited hook—the bait being made to resemble some object on which the animals naturally prey. The art is so termed, according to some, because an angle, as it were, is formed by the apparatus when held over the surface of the water; while others trace it to the angular shape of the hook, as originally fashioned of wood or bone, such being still the form and materials employed by savage nations. Whatever the origin of the term, the practice of taking fish in this excusably crafty manner, either for profit or for amusement, is of great antiquity, as we may learn from the mention made of it by the prophet Isaiah: 'The fishers also shall mourn, and all they that cast angle into the brooks;' chap. xix. verse 8. As well as fishing with nets, the practice has continued through all ages to the present time, and in almost all countries. In the British islands it has long formed a favourite pastime among every class of society, lay and clerical, and to all presents many features of attraction. As the sport is pursued on the banks of rivers or lakes, in the midst of purely natural scenery, and in weather which invites to out-of-door recreation, everything conspires to render it in a peculiar manner exhilarating and healthful, when indulged in with judicious moderation.

No kind of amusement has been the object of such frequent description as angling. Hundreds of treatises have been written descriptive of the sport in all its departments, and with reference to all varieties of fish and the waters to which they resort. Indeed, several of our rivers are the subjects of illustrated monographs, detailing not only what is peculiar to the angling of their waters, but whatever, in the way of anecdote, tradition, or history, seems likely to render the practice of the 'gentle craft' inviting and agreeable. The first writer of note on the subject, and who has been acknowledged the great father of the angle, was Izaak Walton—born at Stafford 1593, died 1683—who in the year 1653 gave to the world his *Complete Angler*, a work afterwards enriched with additions by his friend Charles Cotton, and which till this day is esteemed not more for the correctness of its details than the singularly happy humour of its apologues, poetical pieces, and disquisitions. According to old Izaak, all recreations sink into insignificance in comparison with angling, which in almost every page he lauds for its moral qualities, and the health and happiness it is calculated to yield.

GENERAL CHARACTERISTICS OF FISH.

The fish which are the object of attention to the angler are all confined to fresh water, and are chiefly found in rivers or small brooks; some are found in lakes and ponds. All, except eels, have a pretty uniform character—more fully detailed under the head ZOOLOGY—

though differing in appearance and size. Their form is suitable in a remarkable way to give celerity and ease of motion—a small head swelling into a thick body, and tapering off towards the tail. Those designed for slower motion are more thick and lumpy in figure. The power of moving quickly, and of buoying themselves in the water, is very nicely provided for by their specific gravity, which is nearly the same as the water in which they move; in other words, they are about the same heaviness as the water which they displace, and consequently they are almost destitute of any feeling of weight. On this account, they are not in the slightest degree encumbered in their movements, and are difficult to tire in their exertions.

The tail is the grand instrument of motion; it is a thin delicate membrane, whose smallest bending to and fro impels the body forward in any required course. The fins are principally required for balancing and regulating the movements of the fish; if any be cut off, the animal loses the power of keeping itself with the back fairly upwards; should it be deprived of the tail, the ability of moving forward is gone, and it lies a hulk at the mercy of its enemies. Not the least remarkable peculiarity in the economy of the fish is the existence of an air-bladder, by the dilatation or contraction of which it possesses the power of rising or sinking in the water, according as it feels inclined. It may be observed that fish, while in water, are constantly moving the gills, which is analogous to the act of breathing. The water sucked in by the mouth, and vented by the gills, contributes a minute portion of air, but enough to keep up the circulation of the blood and sustain life: if we were to tie up the gills, the fish would be immediately suffocated. The blood of fish is cold, being only about two degrees warmer than the water in which they live.

The senses of fish have engaged much attention from naturalists. Their quickest sense is that of sight; but they are destitute of the power of contracting the iris of the eye, so as to accommodate themselves to different degrees of light. In ordinary circumstances, this is of no consequence, as the water diminishes the intensity of light, and the animal has the means of retiring to the bottom, or into holes, to escape the glare of the mid-day sun. As far as experiments have gone to prove, fishes possess little or no sense of hearing; but the senses of taste and smell are largely developed: they are also provided with an appetite of boundless voracity.

'Every aquatic animal that has life,' observes Daniel, 'falls a victim to the indiscriminate voracity of one or other of the fishes. Insects, worms, or the spawn of other tenants of the waters, sustain the smaller tribes; which in their turn are pursued by millions larger and more rapacious. A few feed upon mud, aquatic plants, or grains of corn; but the far greater numbers subsist upon animal food alone; and of this they are so ravenous as not to spare those of their own kind. That there are vegetables in both fresh and salt waters admits of no doubt, and these may furnish food to particular fishes; but those sorts are few—perhaps no one kind can be pointed out that subsists entirely upon them; and although most fishes eat flies and terrestrial worms when they come in their way, yet in the immeasurable waste of waters surrounding this globe, the swarms of fishes are so immense, that the subsistence to be derived from the above sources appears to be altogether disproportioned to their wants, and those of a smaller size seem to constitute the principal food of nearly all the fishes known to us. Charr kept in a pond, if scantily supplied, frequently devour their own young; other fish, that are larger, go in quest of more bulky prey—it matters not of what sort, whether of their own or of another species. If we turn our attention, in this argument, to sea-fish, those with the most capacious mouths pursue almost everything that exists, and often meet each other in fierce opposition, when the fish which has the widest throat comes off with victory, and devours his antagonist.

'The voracious fishes differ widely from the predatory kinds of terrestrial animals; they are neither limited in their number nor solitary in their habits. Their rapacity is not confined to a few species, one region of the sea, or individual efforts. Almost the whole order is continually irritated by the cravings of an appetite which excites them to encounter every danger, and which, by its excess, often destroys that existence which it was intended to prolong. Innumerable shoals of one species pursue those of another through vast tracts of the ocean, from the vicinity of the pole to the equator. The cod pursues the whiting, which flies before it from the bank of Newfoundland to the southern coasts of Spain. The cachalot drives whole armies of herrings from the regions of the north, devouring at every instant thousands in the rear. Hence the life of every fish, from the smallest to the greatest, is but a continued scene of rapine; and every quarter of the immense deep presents one uniform picture of hostility, violence, and invasion.

'In these conflicts, occasioned by the voracity of the different kinds of fishes, the smaller classes must have long since fallen victims to the avidity of the larger, had not nature skilfully proportioned the means of their escape, their numbers, and their productive powers, to the extent and variety of the dangers to which they are unceasingly exposed. To supply the constant waste occasioned by their destruction in the unequal combat, they are not only more numerous and prolific than the larger species, but, by a happy instinct, are directed to seek for food and protection near the shore, where, from the shallowness of the water, their foes are unable to pursue them. These, however, yielding to the irresistible impulse of hunger, become plunderers in their turn, and revenge the injuries committed on their kind by destroying the spawn of the greater fishes.'

That fishes are liable to diseases arising from variations of temperature and other causes, there is no reason to doubt; but few are ever seen dead in the water, there being too many scavengers of the deep to allow of this waste of food. In general, the weak fall a prey to the strong before the period of natural death. It is understood that fishes possess a blunted nervous energy, which renders them almost insensible to any ordinary infliction; and so mean are their reflective faculties, that after escaping from a hook which has lacerated their palate, they will in the next minute catch at a similar bait, and be hooked a second time and drawn from the water. A number of years ago, two young gentlemen, while fishing in a lake in Dumfriesshire, having expended their stock of worms, had recourse to the expedient of picking out the eyes of the dead perch they had taken, and attaching them to their hooks—a bait which this fish is known to take as readily as any other: one of the perch caught in this manner struggled so much when taken out of the water, that the hook had no sooner been loosened from its mouth, than it came in contact with one of its eyes, and actually tore it out. In the struggle, the fish slipped through the holder's fingers, and again escaped to its native element. The disappointed fisher still retaining the eye of the aquatic fugitive, adjusted it on the hook, and again committed his line to the waters. After a short interval, on pulling up the line he was astonished to find the identical perch that eluded his grasp a few minutes before, and which literally perished in swallowing its own eye.

Fishes are exposed, not only to external foes which it requires all their dexterity to elude, but to the torment of parasitical marauders in their own person. Besides creatures which make a lodgment in the intestines, various parasites fix themselves beneath the scales, in the mouth, and upon the gills. Salmon, perch, trout, and other fresh-water fish, are preyed upon in this manner by different species of lice; and as some of these parasites

cannot live in salt water, it has been supposed that one of the reasons for the salmon migrating to the sea is to relieve itself from the lice (*Lernea salmonia*) which have adhered to its gills. The trout louse, or *L. truttæ*, is not unknown to fishers.

FISHING-TACKLE.

The equipment of the angler consists mainly of his rods, lines, hooks, and baits, with the means of keeping them in order, or supplying their place in the event of an accident. To these, dealers have added numerous accessories, more cumbrous than useful, and always more sought after by the holiday angler than the genuine disciple of Walton. As one-half the art depends on proper equipment, we shall describe the leading implements in detail.

The Rod.

This is the chief implement of the angler. It ought to be strong and elastic, and should bend, on being waved, through its upper half, but particularly at the small tapering point. The wood most suitable is hickory or ash, with yew for the upper part, to which a point of whalebone is attached. Young anglers are too apt to select rods measuring from twelve to sixteen feet in length for trout-fishing, when in reality a simple, and not too elastic wand of about ten feet for trout, and eighteen feet for salmon, will amply suffice. Whatever be the length, it must be quite straight, and on all occasions bend back to its original straightness. If there be a single knot in the timber, reject it, for it will certainly snap at the first severe pull or jerk. It should be varnished, to protect it from the action of the water. The rod is not all of one piece; for the sake of convenience, it is divided into three, and sometimes as many as six pieces in the length. These pieces are usually joined by means of screws and ferules; but if this be the plan of the rod offered to your choice, take care to see that these metal junctions do not impair the bending properties of the instrument, or render it too heavy. Rods of a plain kind made in the country are spliced with wax-threads, and these are generally more serviceable than the fine-looking rods manufactured in cities. Listen to what John Younger of St Boswell's—a village on the Tweed—says on this subject: 'To those who reside near the water, I would recommend a rod all of glued and tied joints as best in point of real use, and not so liable to break in the moment of action. Or, indeed, even for travelling, I would prefer tied joints, as wherever a person has time to stop to fish, though only for a day or two, he has at least five minutes to spare for tying his rod in a sufficient manner. Rods are often breaking at brass joints; and those who use them, instead of bringing in a back-load of fish, are constantly arriving home from the water, telling you: "I've broken my rod!" Such sickening news may generally be, prevented by tied joints.'

At the bottom of the rod, where it is grasped by the hand, a brass reel or *pirn* is attached, and on this the line is wound. It should be simple in its mechanism, so as to allow of expeditious winding or unwinding. The line is conducted from the reel to the upper termination through small wire-loops, in Scotland called *mylies*, which are fixed to the rod; these must be in an even line when the pieces of the rod are joined together, and be about a foot asunder. In *fashionable* rods, the mylies are small rings held by wires to the rod, and they conveniently fall flat when the rod is not in use. Good serviceable rods require no such elegance of design. The angler who is skilled in his art cares nothing for finery of apparatus, and will pull out dozens of fish in a day with an instrument which many would think not worth the carrying. Indeed, one of the best day's sport ever we enjoyed was with a sapling ash, lithe and green, from the banks of the river over which it was plied with such memorable success.

Lines.

These should be long, smooth, and flexible, and of a material which will not be easily injured by wet. These qualities are found in lines made of horsehair and gut, which we recommend in preference to any other. The part of the line which is wound on the reel, and goes along the rod, is called the *reel-line;* and being designed to be let out only on occasions when a fish darts off with a hook in its mouth, it need not be so thin and light as the bulk of the portion termed the *casting-line.* A better cast can be made with a heavy, than with a very light line, as it is not so apt to be affected by the wind. The reel-line, which may be about thirty yards in length for ordinary trout-fishing, and about sixty for salmon, is formed by spinning together horsehairs, so as to make a fine even cord. As it is troublesome to make, it should be purchased from a respectable dealer in fishing-tackle.

The casting-line, which is united by a loop to the reel-line, may be also of horsehair, but of a smaller texture and lighter in weight. It should be five lengths of hairs in extent, the uppermost length being eight hairs in thickness, and gradually tapering to the lowest length. To the lower end of this casting-line is added the *gut-line*, which is the part that actually falls upon the water, and therefore requires to be very fine. It consists of a series of strong gut, and to it is attached the short lengths, or casts of gut on which are the hooks. In some instances, casting-lines are altogether made of gut, but those of hair are better, on account of their greater elasticity.

On the article gut, Mr Stoddart, in his *Art of Angling*, has the following observations: 'This article, originally imported from the East, and now brought in considerable quantities from Spain and Italy, is, as far as we have been able to learn, fabricated from the male silkworm in a state of decomposition. The operation is principally conducted by children, and consists in removing the external slough of the worm with the fingers, elongating at the same time the gluey substance which composes its entrails. To do this properly, requires some care and attention. Should the worm be kept too long, a hard crust forms itself over it, in destroying which the application of the nail is necessary; hence the gut becomes flattened, and loses much of its value. The sinews of herons and other birds are also manufactured in Spain into a sort of gut, and are much used, although unwittingly, by our salmon-fishers. Worm-gut varies in length from nearly two feet and downwards. We have seen, however, an article very closely resembling it from the Archipelago, which measures at least a yard and a half. This is not to be confounded with sea-weed, although a vegetable fibre, and drawn out of a plant. It is much stronger, and better suited for angling. The inhabitants of the Greek islands use it for catching mullet, and will often toss a fish some pounds' weight over their heads by a thread or two. We ourselves have found it excellent for the larger sorts of tackle. Animal gut is, however, more generally used, and better adapted for trouting. It ought to be small, round, and transparent, without any flaw or roughness. When worn or disordered, the application of a piece of India-rubber will at once renovate it. In joining threads together for the purpose of making casts, the single knot properly drawn is quite sufficient. One should avoid clipping the useless extremities too closely in this operation, as in that case the knot is somewhat liable to give way. Gut, to keep well, should be moistened with fine oil—almond or olive—and stored in oiled paper.'

To these recommendations we may add, that lines of all kinds should be kept dry. On returning from a fishing-excursion, draw out the line, and let it be thoroughly dried by waving in the air before being wound up or laid aside. When to be again used, look it over, giving it a gentle tug here and there to try its strength, and repair

damaged parts. On coming to the water-side, and just before throwing, allow the casting-line to be wetted in the water, and this will at once give it smoothness and elasticity.

Hooks.

These are small instruments made of tempered steel, and of whatever size, they require to possess the qualities of lightness and great strength. They have been always principally manufactured at two places—Kendal in Westmoreland, and Limerick in Ireland. The Kendal circular bends, as they are called, are reckoned the best hooks of a small size, while the Limerick hook is preferable for salmon. Many of the fish-hooks of ordinary English makers are worthless. Hooks range in size from about an inch and a half in length down to a quarter of an inch, with a proportional diminution of thickness. Some makers number them from No. 10, the smallest, to No. 20, the largest; while others number from 1, the largest, to 14, the smallest. The Limerick hooks are denoted by letters, commencing with A, and so on. In purchasing hooks, see that the body is of equal thickness throughout, and that the barb is boldly yet firmly set. Try their power of resistance by forcing the bend with the fingers, and urging the point against the thumb-nail. Hooks for fly-fishing should be thinner in the shank than those designed for bait. An angler should keep a small stock of hooks of various sorts, to be ready on all emergencies; with the tackle to which they are attached, they require to be kept very dry.

Landing-net—Gaff—Drag-hook.

The *landing-net* is considered in England a necessary implement for an angler, but in our opinion, they must be poor hands at fishing who cannot drag a trout or any similar small fish from the water after hooking it without resorting to such a cumbrous apparatus. Perhaps it is found to be essential, in consequence of the feebleness of the rods and tackle usually employed. It consists of a small bag-net stretched on a hoop at the extremity of a pole four or five feet in length. Mr Blaine, in his *Encyclopædia of Rural Sports*, seems to think a landing-net of first importance; and for the use of tyros in the art, he gives the following directions: 'In fly-fishing, when the line is long, and there is not much space to step backward, or the reel clogged, it is necessary sometimes to lay hold of the line with one hand; but this should be done with great caution, and then only after the fish is well-nigh spent, or one struggle may carry away line, hook, and fish. In all other cases, avoid touching the line, if possible; but having sufficiently played the fish, whether taken by bottom or by fly-fishing, bring him within reach of the landing-net, and then carefully conduct or slide the net obliquely under the foreparts of his body, which, if the fish be completely exhausted, will fall into it; but if he has still sufficient vigour, it will be prudent rather to slide him over the net than the net under him. It must have occurred to every angler to have supposed a trout or salmon to be completely spent, which, the moment he has been touched by the net, or has even caught sight of the fisher, has sprung off with most annoying violence. Against such an accident, it is prudent to be ever prepared by keeping the rod in an upright position, acting on a tightened line, but yet so disposed that it can run at liberty if required. When the head and shoulders of the fish are once fairly within the net, a slight turn of it will take in the whole body, and the net being then kept horizontally, will insure his safety; for with the head downwards, he cannot disengage himself from the net: but if he be received tail foremost, as is sometimes done in deep waters, from overhanging banks, &c., beware of his plunges.'

The *gaff* is another aid to landing fish, and is employed in cases in which the landing-net would be too small. It is used chiefly for landing salmon, and consists of a peculiarly shaped hook at the end of a staff. When the salmon flounders about, and incommodes the fisher, he is expected to secure the animal, and prevent it from breaking his line and rod by hooking it with the gaff at the gills, the tail, or any part he can conveniently lay hold of.

The *drag-hook* is an implement with three bent prongs or hooks, with a long cord-line attached. It is used for casting into rivers to clear away any object at the bottom upon which the hook is caught. We pity the angler who attempts fishing in weedy puddles requiring such a clearer of hinderances.

Angler's Pocket-book, &c.

The angler's equipment is completed by the addition of a basket for holding his fish, which is slung on the back by a shoulder-belt; also a pocket-book for holding hooks and other trifles; and a round flat tin box for his fly-casts. Many carry their supply of fly-casts wound round their hat, and some keep them within the leaves of their pocket-book. This pocket-book, which is the storehouse of all kinds of odds and ends—we have seen a good one made out of an old pocket almanac—should have two or three pockets for holding an assortment of hooks, silk thread, stuff for making flies, gut, wax, small cord, fly-nippers, scissors, &c.—all to be used in case of breakage of tackle or rod, or any other accident. In fishing for perch, gudgeons, bream, &c., a small float is often used. Floats are made of cork, quill, reed, and other materials; and a choice, according to circumstances, can be added to the contents of the pocket-book.

For an angling dress, all finery is worse than useless. Fish are easily scared with the appearance of any light or showy object on the banks. Let the angler, therefore, dress himself in a plain dull-coloured suit, with a hat equally sober in its aspect; and let him use only strong shoes or boots which will not be injured by water. A suit of gray-coloured Tweed, with a felt or flap hat, is at present reckoned orthodox; and to these we may safely suggest the addition of a pocket-flask, to be filled at the outset of the day's excursion according to the taste of the bearer.

Baits.

A bait is any substance put upon a hook to act as a lure to the fish; and when used, the baited hook is dropped into, and allowed to sink in the water, instead of being kept near or upon the surface, as in the case of fishing with fly. The materials, living and dead, used for bait are very numerous; but the leading kinds are worms, maggots, minnows, insects, and salmon-roe. The hook employed in either case is tied by the shank to the gut with waxed silk, and the preparation is therefore not at all difficult. When dressed to the gut, it is called bait or worm tackle.

Worms used for bait are of various sorts; but that which is most commonly employed is the lob or garden worm, a long reddish-coloured reptile found in abundance in many gardens, grass-plots, under old cow-droppings in fields, and in any rich old soil. They may be dug up with a spade, or caught while crawling from their holes at twilight, and particularly after heavy showers. 'He who seeks them,' says Daniel, 'must move cautiously without noise, or they will quickly retreat into the earth; draw them gently out of their holes without nipping; those that sever in taking must be thrown away, as they will soon become putrid, and infect the others. When as many are collected as are wanted, having plenty of good moss freed from dirt, dip it into clean water, and wring it nearly dry; put it into an earthen pot proportioned to the quantity of worms, laying it regular, and forcing it down with the hands; strew the worms on the surface, after dipping them in clear cold water to rid them of the soil that may adhere to them; such as are not injured will soon bury themselves in the moss, and those that do not, must the next morning be picked off as useless. They must be inspected every three or four days, the dead ones removed, and have fresh moss, or that wherein

they have been kept, well washed and picked, and the water squeezed out at least once a week. They must be so placed, summer and winter, as to be safe from the extremity of the weather at both seasons. In a week's time, they will be fit for use; and upon the angler coming home from fishing, he will return from his worm-bag into the pot those which he has not used. By observing the above carefully, they may be kept a month in summer, particularly by now and then giving them, drop by drop upon the moss, a small quantity of new milk and the yolk of an egg well beaten together and warmed, so as to thicken it; but when a stock of lob-worms is meant to be retained for a considerable length of time, a large vessel must be filled half or three-quarters full of good mould, in the middle of which is to be placed some moss or old coarse linen cloths, hopsack, or rags wetted. In hot dry weather, clean water must be sprinkled upon the earth with a watering-pot, so as to keep them moist, but not wet; they may thus be preserved as long as is requisite; and a week before angling, what are wanted may be drawn from the store, and put into moss to scour themselves.' *Fresh* worms, however, are now considered best for salmon. Another worm, which is found in dunghills, called the *brandling*, from its striped appearance, forms a good bait, but it is seldom used.

Maggots, or the larvæ of insects, as is well known, are found on fly-blown meat or any putrid animal substances: very fine ones are procured from game in a *high* condition. Daniel calls these creatures *gentles*, and describes them as of great virtue in certain kinds of fishing. 'Gentles,' he observes, 'may be procured almost at any time at the tallow-chandlers, and should be kept in oatmeal and bran, as bran by itself is too dry. Those who live in or near London may buy them in proper condition for the day on which they wish to use them; but for the accommodation of those who reside in the country, remote from such convenience, the best modes of breeding them will be here mentioned, in order to prevent disappointments. Coarse fish, such as *chub* and *roach*, may be laid in an earthen pot, in the shade, and will soon be fly-blown. When the gentles are of the proper size—but not before—put some oatmeal and bran to them, and in two days they will be well scoured, and fit to fish with; in about four more, they become hard, assume a pale-red colour, and soon after change to flies. The red ones should not be thrown away, as frequently roach and dace take these with a white one, in preference to all other baits. Some have recommended a piece of liver suspended by a stick over a barrel of clay, into which the gentles fall and cleanse themselves; but clay will not scour them, and, besides, they fall from the liver before they have attained their full size. The before-mentioned is a less disgusting plan. For a short time after oatmeal and bran are put to the gentles, the fish in which they are bred will be found perfect skeletons, and may be thrown away; however, if they are to be bred from liver, it should be scarified deeply in many parts, and then hung up, and nearly covered over, as in that way the flies will blow it better than when wholly exposed. In two or three days, the gentles will be seen alive; the liver is then to be put into an earthen pan, and there remain until the first brood are of full growth. A sufficient quantity of fine sand and bran—letting the liver remain—is then to be put into the pan, and in a few days they will come from the flesh, and scour themselves in it. The liver should then be hung across the pan, and the latter brood will soon drop out, and be fit for use; and by thus breeding them in October, and keeping them a little warmer than those bred in the summer, until they arrive at their full growth, and afterwards putting them in the same pan into a dampish vault, they may be preserved for winter-fishing. Those bred in summer, but for the bran and sand, would soon sink into a dormant state. The skins take on a blackish red, full of white matter, and shortly after become flies. Those produced in autumn, from whatever substance, will continue in this state all the winter, provided they can shelter themselves under the surface of the earth in fields, gardens, &c.; and in the warm weather of the ensuing spring they change into flies, thus preserving their kind from year to year. Gentles are so universal and so alluring a bait, that the angler should never be unprovided with them. Trouts have been taken with them in clear water, when they have refused all kinds of worms and artificial flies.'

Caddis, or *cad-bait*, is another kind of larva, inhabiting pieces of straw, or little cylinders formed of bits of stick or sand at the sides of rivers. They are always most deadly in the rivers from which they have been taken, and are found to answer best in tributary streams. Daniel, in making some observations on this kind of bait, says: 'Some of them enclosed in a very rough shell, found among weeds in standing waters, are generally tinged green; others are bigger than a gentle, and of a yellowish hue, with a black head: they form an excellent bait, and are found most plentifully in gravelly and stony rivulets, and by the sides of streams, in large rivers among stones.

'To collect them, turn up the stones, and the best will adhere to them. When the quantity wanted is obtained, put them into a linen bag for five or six days, dip them, together with the bag, into water once a day, and hang them up; they will then turn yellow, become tough, and fitter for angling than when first got from the brook. If meant to be kept long, they must be put into a thick woollen bag, with some of the moist gravel or sand from the same rivulet whence they are taken; they must be wetted twice a day, but oftener in very hot weather. When you carry them abroad, fill the bag with water, and holding the mouth of it close, let the water run from them; in this way they may be kept three weeks. Another way of preserving them is by placing them in an earthen pot full of river-water, with some of the gravel they were bred in at the bottom; but the preceding method is preferable. Some use bait-pans of different sizes for insects, the tops punched full of holes, not so large as to admit of their escaping when placed in the river, which not only keeps them cool, but supplies them with aliment in the fresh water; some keep them in moss in a woollen bag on a damp floor, taking care that the bag retains a proper moisture. A third mode of preserving caddis, and also grasshoppers, caterpillars, oak-worms, or natural flies, is to take the green withy bark from a bough six or seven inches round, and about a foot in length: turn both ends into the form of a hoop, and fasten them with a large needle and thread; stop up the bottom with cork, and bore the bark full of holes with a red-hot wire; tie over it a colewort leaf, and lay it in the grass every night. In this manner caddis may be preserved until they turn to flies. When grasshoppers are to be preserved in the case, some grass must be put into it.

'In angling with caddis, the line, when all out, should be as long as the rod, for three lengths next the hook, of single hairs, with the smallest float, and the least weight of lead that the swiftness of the stream will allow to sink; and that may be aided by avoiding the violence of the current, and angling in the returns of a stream, or in the eddies betwixt two; which are also the most likely places wherein to kill fish, either at the top or bottom. The caddis may be at times, with very good effect, joined to a worm, and sometimes to an artificial fly, to cover the point of a hook; and also two or three together may be put in upon the hook. It is always, however, to be angled with at the bottom, especially when by itself, with the finest tackle, and at all seasons forms a most holding bait for trout and grayling.'

Minnow bait.—Minnows are a small fish, from an inch to two inches in length. They swim in flocks, and may be captured by a hoop-net on the end of a staff,

or more simply, by a crooked pin baited with a small worm. Anglers generally hire a boy to catch a quantity of them. The tackles used for minnow bait are various in their formation: some are single hooks; others, a pair of hooks dressed back to back; and a third kind are a series of pairs, one above another. We cannot do better than give Mr Stoddart's description of these deadly instruments, and the mode of baiting them. He alludes to Kendal hooks:

'The most simple, and in some places the most deadly, is a common single bait-hook. This we insert through the back of the minnow, and drawing it out, run below the gill, allowing the barb to protrude from the mouth; we then tie up the tail along the gut, either with a piece of silk thread, or more expeditiously with the gut itself, hitched over the part. This is angled with in the same manner as the worm, allowing plenty of time for the fish to gorge. A tackle similar to it may be used in standing-pools or lochs. Here, however, the shank of the hook—a long one—is loaded, and the bait allowed to descend rapidly towards the bottom. Large cautious fish are sometimes taken by this method of angling. Of all minnow-tackles, that with swivels is the commonest and most agreeable to employ. There are many ways of constructing it. Two of these we shall mention as preferable to all others. One is simply a large hook, No. 11, fastened to good round gut with two smaller ones, No. 7, tied back to back above, and looped in the dressing, so as to slide along, and shorten or lengthen the tackle to the dimensions of the bait. In using it, enter the lowermost hook through the mouth, and bring it out near the tail of the minnow; insert one of the hooks on the slider, through its lips, noticing that the fish be slightly curved, so as to spin properly. The other tackle is composed of six hooks, No. 7, dressed in pairs, and is angled with only when the trout are in a taking mood. Two or more swivels are required for both of these contrivances—the lowermost fastened about two feet or so above the bait. Leaden pellets may also be used, but many think them unnecessary. Some anglers attach behind the whole apparatus an extra hook, No. 12 or 13, dressed upon a hog's bristle, which, should the trout miss the minnow, is apt to catch him, when retiring, by the middle or other part of the body. This is a superfluity, and, like many superfluities, does more harm than good, alarming the fish without securing them. Tackle for trolling with parr or small trout ought to be constructed on the same principles as the minnow-tackle; only the hooks should be larger, and dressed upon gimp instead of gut. Snap-hooks, also, are in use for this kind of angling. Small silk cord oiled will be found the best trolling-line.'

The perfect insects used for baits are grasshoppers, crickets, day-flies, spring-flies, May-flies, humble-bees, and various others. The ephemeræ, or those fragile creatures that live but for a day or even a few hours, and therefore called day-flies, are found sporting by the low banks of rivers in warm weather, and form a taking bait for trout and some other fish.

Salmon Roe.—The efficient use of this as a bait is a modern discovery, and has added largely to the angler's means of capturing the finny tribes. It is prepared for use by salting it a little, and drying it to a state in which it will keep.

Mr Boyd, Secretary of the St Ronan's Angling Club, who has written a good deal upon this, as well as on other subjects connected with angling, makes the following observations upon roe-fishing: 'Fishes are acutely sensible to the touch; the sense of smelling, for which appropriate nerves are elaborately distributed, gives them the faculty of detecting the existence of food or enemies at great distances. The roe-fisher will therefore find that the previous baiting of the pool, before commencing operations, will much add to his success.' He goes on to say that though he has met with great success during floods, still this bait answers well whilst the streams are much reduced, some of his most successful takes having occurred while the rivers were in this state. He says: 'When the rivers continue in this state (reduced), two small hooks, with their shanks shortened, and tied back to back, ought to be used, and so baited as to completely envelop the hooks, which must be attached to gut of the finest description; and as long as the water remains small, a little before sunrise will be found the most deadly time for killing the larger description of trout. The Limerick-shaped hooks I consider the best for roe-fishing; in particular when a single hook is used, which ought to be invariably the case in turbid or swollen waters. The only objection to the roe cured in the pea, is that of its being not sufficiently tough upon the hook, and therefore stolen with such ease by the fish as to require frequent rebaiting. In this respect, the pasted roe has the advantage, and at the same time equally killing as that cured in the pea. The sea-trout roe will be found much more durable as a bait than that of the salmon, in consequence of its natural toughness, and in no degree less efficacious. To be successful in roe-fishing, very much depends upon the quality of the roe, which ought invariably to be cured so as to retain its natural fishy smell; and to preserve this, it will require to be regularly kept in a dry situation, and exposed as little as possible to the air. The size of the bait ought never to exceed that of a small coffee-bean, and to be put on the hook in a globular form, which fish most readily gorge without detecting the steel. In all my experience in fishing, which has been considerable, I have almost invariably found, when using the pasted or gummy roe, that, by allowing the trouts time to swallow the bait, I seldom or never failed in killing the fish. Salmon, and more particularly sea-trout, take roe readily in turbid water. The bait, however, will require to be considerably larger than that recommended for the common trout.'

Artificial Flies.

Hooks dressed up so as to bear something like a resemblance to actual live flies, are by far the most important lures employed by the angler. The principal materials employed in dressing are light portions of cock's hackle or other feathers, to form wings, the fur of a hare's ear or some other substance to make the body, and waxed silk thread, by which the whole is tied in an artful manner on the shank of the hook. A whole sheet might easily be filled with descriptions of artificial flies suitable to different fish, waters, and seasons; but the bulk of what has been written by Walton, Daniel, and many others, is now considered superfluous, experienced fishers having arrived at the conclusion, that fishes in general are such eager and heedless fools as to be satisfied with a very limited choice of deceptions. The author of the article Angling, in the *Encyclopædia Britannica*, has some clever remarks on this branch of the art:

'As simulation,' says he, 'consists in the adoption or affectation of what is not, while dissimulation consists in the careful concealment of what really is—the one being a positive, the other a negative act; so the great object of the fly-fisher is to dissimulate in such a manner as to prevent his expected prey from detecting the artificial nature of his lure, without troubling himself by a vain effort to simulate or assume with his fly the appearance of any individual or specific form of insect life. There is, in truth, little or no connection between the art of angling and the science of entomology; and therefore the success of the angler, in by far the greater proportion of cases, does not depend on the resemblance which subsists between his artificial fly and the natural insect. This statement is no doubt greatly at variance with the expressed principles of all who have deemed fishing worthy of consideration, from the days of Isaiah

and Theocritus, to those of Carrol and Bainbridge. But we are not the less decidedly of opinion, that in nine instances out of ten, a fish seizes upon an artificial fly as upon an insect or moving creature *sui generis*, and not on account of its exact and successful resemblance to any accustomed and familiar object.

'If it is not so, let us request to be informed upon what principle of imitative art the different varieties of salmon-fly can be supposed to bear the most distant resemblance to any species of dragon-fly, to imitate which we are frequently told they are intended? Certainly no perceptible similarity in form or aspect exists between them, all the species of dragon-fly, with the exception of one or two of the sub-genus Calepterix, being characterised by clear lace-like pellucid wings, entirely unadorned by those fantastic gaudy colours, borrowed from the peacock and other "birds of gayest plume," which are made to distinguish the supposed resemblance. Besides, the finest salmon-fishing is frequently in mild weather during the cooler seasons of the year, in autumn and early spring, several months either before or after any dragon-fly has become visible on the face of the waters, as it is a summer insect, and rarely makes its appearance in the perfect state until the month of June. If they bear no resemblance to each other in form or colour, how much more unlike must they seem when, instead of being swept like lightning down the current, as a real one would be, the artificial fly is seen crossing and recrossing every stream and torrent with the agility of an otter and the strength of an alligator! Or, darting with regular jerks, and often many inches under water, up smooth continuous flows, where all the dragon-flies on earth, with St George to boot, could not maintain their place a single second! Now, as it is demonstrable that the artificial fly generally used for salmon bears no resemblance, except in size, to any living one—that the only tribe which, from their respective dimensions, it may be supposed to represent, does not exist in the winged state during the period when the imitation is most generally and most successfully practised—and if they did, that their habits and natural powers totally disenable them from being at any time seen under such circumstances as would give a colour to the supposition of the one being ever mistaken for the other—may we not fairly conclude that, in this instance at least, the fish proceed upon other grounds, and are deceived by an appearance of life and motion, rather than by a specific resemblance to anything which they had previously been in the habit of capturing? What natural insect do the large flies, at which sea-trout rise so readily, resemble? These, as well as grilse and salmon, frequently take the lure far within the bounds of the salt-water mark; and yet naturalists know that no such thing as a salt-water fly exists, or at least has ever been discovered by their researches. Indeed, no true winged insect inhabits the sea. What species are imitated by the palmer, or by three-fourths of the dressed flies in common use? An artificial fly can, at the best, be considered only as the representative of a natural one which has been drowned, as it is impossible to imitate the dancing or hovering flight of the real insect over the surface of the stream; and even with that restricted idea of its resemblance to nature, the likeness must be scarcely perceptible, owing to the difference of motion and the great variety of directions in which the angler is obliged to drag his flies, according to the nature and special localities of the current, and the prevailing direction of the wind.

'We are therefore of opinion that all, or a great proportion of what has been so often and sometimes so well said about the great variety of flies necessary to an angler—about the necessity of changing his tackle according to each particular month throughout the season—about one fly being adapted solely to the morning, another to noonday, and a third to the evening—and about every river having its own particular flies, &c., is, if not altogether erroneous, at least greatly exaggerated and misconceived. That determinate relations exist between flies of a certain colour and particular conditions of a river, is, we doubt not, true; but these are rather connected with angling as an artificial science, and have but little to do with any analogous relations in nature. The great object, by whatever means to be accomplished, is to render the fly deceptive; and this, from the very nature of things, is continually effected by fishing with flies which differ in colour and appearance from those which prevail upon the water; because, in truth, as we shall afterwards have occasion to shew, none else can be purchased or procured. Even admitting for a moment the theory of representation, when a particular fly prevails upon a river, an artificial one in imitation of it will never resemble it so closely as to appear the same to those below (that is, the fish); on the contrary, a certain degree of resemblance, without anything like an exact similitude, will only render the finny tribe the more cautious through suspicion, while a different shape and colour, by exciting no minute or invidious comparisons, might probably be swallowed without examination. Indeed, it seems sufficiently plain that where means of comparison are allowed, and where exact imitation is at the same time impossible, it is much better to have recourse to a general idea than to an awkward individual representation.'

Mr Stoddart, one of our most experienced anglers, entertains a similar opinion. 'The colours of water and sky,' he observes, 'are the only indicators which can lead us to select the most killing hook, and even these are often deceptive. We have fished in one stream where dark, and in the next, red flies took the lead. There is no trusting to the fancy in certain places. On Tweed, we have seen it veer about like the wind, in one moment, without a note of preparation. Most rivers, however, are more steady; and when the water is of a moderate size, may be relied on with at most two sorts of flies all the year round. For ourselves, our maximum in every Scottish stream is reduced to only four descriptions of artificial flies, with one or other of which we engage to catch trout over all the kingdom. Knowledge and practice have convinced us of the needlessness of storing up endless and perplexing varieties, which some do, in order to appear knowing and scientific.'

The following descriptions of flies and spiders have been highly recommended to us by Mr Boyd, an old and experienced angler, and who has found them to be most killing, particularly in the rivers and tributaries of the border counties of Scotland. He says: 'The flies and spiders with which we have achieved our greatest takes, were purchased at Mr Lang's fishing-tackle establishment, South Hanover Street, Edinburgh.* We may add with much truth, that we have invariably found the *spiders* more deadly than flies; and with regard to salmon flies, we are decidedly of opinion that no one, however ingenious, can make a fly, be the colour what it may, that will not kill, provided he keeps within bounds with regard to size. We have, however, found from extensive experience, that the two flies here represented and described, are superior to all others we have hitherto tried.

Salmon Flies.

'They are dressed with the following materials:

'No. 1. Tail—crest-feather from golden pheasant; tip—gold tinsel and orange silk, with two turns of ostrich herl; body composed of claret-coloured pigs' wool and mohair mixed, with a little pigs' wool at the head, of a light-blue shade; wound with silver tinsel and dark-red

* The originals from which the drawings on next page were prepared, were furnished by Mr Lang.

hackle, with blue jay's feather for shoulders; wings—from the teal-duck or widgeon, distinctly marked or barred; head—of black ostrich herl.

1 2

'No. 2. Tail—crest feather from golden pheasant; body composed of pigs' wool and mohair mixed, of a dark-cinnamon shade; wound with silver twist and dark-red hackle; shoulders composed of breast-feather of the argus pheasant; wings composed of golden pheasant tippet or neck feathers, distinctly marked teal, four fibres of blue and red macaw tail-feathers, with pairs of wings from the brown and black barred feathers of the peacock wing surmounting the whole; a blue feather from the kingfisher or blue chatterer on each side of the wings; feelers—from blue and buff macaw tail-feathers; head—black ostrich herl.'

Trout Flies.

Nos. 1 and 2 of the flies, and No. 1 of the spiders in the following list, are represented in the annexed wood-engraving; and we may here mention that the practice of fishing for trout with heavily dressed flies is now considered by the best anglers to be a mistake, especially in streams. Our present authority uses only thinly dressed flies or spiders, and likewise recommends the practice of *frequent* casting; his reason being, that trout almost invariably seize the lure the instant it reaches the water, seldom waiting till the casting-line has swept the stream. He also recommends fishing up the stream, as by that means the fish are less likely to see the angler. To avoid unnecessary fatigue to the arm, the rod should be light and short.

Flies.—No. 1. Wings formed of feathers from the wing of the chaffinch, with a black hackle, tied with slate-coloured silk.

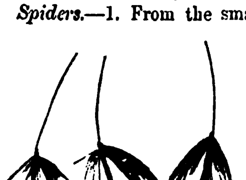
2. Wings composed of woodcock or partridge feathers, and red hackle, tied with yellow silk.

3. Wings formed of the corn-bunting, with a red hackle wound round close to the head, tied with orange-coloured silk.

4. Wings formed from the speckled feather of the teal, with a black hackle wound round close to the head, tied with brown silk. The same wing with a red hackle, tied with yellow silk, also makes a killing fly.

5. Wings from the feathers of the dotterel; body and hackle same as No. 2.

Spiders.—1. From the small feather of the dotterel wing, tied with yellow silk thread.



1 2 1

Flies. Spider.

2. From the small glistening feather taken from the outside of the shoulder of the starling's wing, tied with yellow silk thread.

3. From the neck-feathers of the hill-partridge, tied with yellow silk thread.

4. From the black hen-hackle, tied with small black silk thread.

5. From the blue hen-hackle, tied with yellow silk thread.

6. From a small red cock-hackle, or the small feather of the landrail's wing, tied with yellow silk.

Mr Stoddart offers the following explicit directions for fly-dressing; and every one who wishes to become an adept should make himself master of this portion of the art:

'Our materials for the making up of flies are as follow: Hooks, and small round gut; a pair of brass nippers for twisting hackles; a point for dividing the wings; a pair of fine scissors; orange, yellow, and green silk thread of all sizes; good cobbler's wax enclosed in a piece of soft leather; a hare's ear; some brown wild-drake, teal, and pheasant feathers; the fur of a mouse, squirrel, and water-rat; a few wings of lark, snipe, landrail, and starling; and, lastly, red and black hackles, taken from the neck and head of an old cock at Christmas: these should be fully formed, and free from softness. Plovers' herls, and those of the peacock, are used by some, yet we deem them superfluous; as also tinsel, except for large flies.

'Commencing your operations, the first step is to lay out the intended wings and body before you; wax your silk, and applying one end of it to the gut and hook together, wrap them both round four or five times, commencing a little below the end of the shank, and proceeding downwards; you then fasten, by drawing the disengaged end of the thread through under the last turn of the wrapping. Work the silk upwards to where you commenced, then take your wings, which are still unseparated, and lay them along your hook, so that their extremity or tips shall reach its curve; twirl the thread twice round the upper part, which lies along the shank top; then taking it under, press firm, and clip off the unnecessary portion of the feather; divide with your point or penknife, so as to form the two wings; take up the silk betwixt them, and wrapping again round at the head, bring it back crosswise; then lift your hackle, and lay the root of it down along your hook; whip the thread over, as far as your first fastening; seize the top of the hackle with your nippers, and whirl it round in the same manner; fasten and lengthen the body to your liking with fresh floss silk; fasten once more, and your fly is made. This last fastening ought, in our opinion, to be the same as that used in arming bait-hooks, for which we quote Hawkins's directions:—"When you are in about four turns of the bend of the hook, take the shank between the fore-finger and thumb of the left hand, and place the silk close by it, holding them both tight, and leaving the end to hang down; then draw the other part of the silk into a large loop, and with your right hand turning backwards, continue the whipping for four turns, and draw the end of the silk—which has all this while hung down under the root of your left thumb—close, and twitch it off." When the body of your fly is required to be of hare's ear or mouse-skin, pull out a small quantity of the fur, and lay it along the silk, after the wings are formed; twist together, and then wrap as if the thread were bare, and fasten as above. In making flies, keep all tight, guard against heavy wings and much dubbing; the fibres of your hackle ought to be short, and lie near the head of the fly; they are intended to resemble legs, which in the real insect are always so placed. Such is our method of fly-dressing, commendable both for its simplicity and expedition. It differs, we find, somewhat from that generally practised, being in a manner self-taught, and not encumbered with any unnecessary display.'

Having now described the various parts of the angler's apparatus, and the lures which he generally employs, we proceed to shew how he is to practise his craft when fully equipped for the purpose.

PRACTICE OF ANGLING.

There are two distinct kinds of angling—bait-fishing and fly-fishing, and these are variously practised according to the depth, current, and state of the water, or the nature of the fish sought to be caught.

Bait-fishing.

This kind of angling is practised to a great extent in the Thames, the Lea, and other deep and somewhat dull rivers of England. The fish usually sought for in these waters are gudgeon, dace, roach, bream, chub, barbel, tench, carp, perch, and pike: all are sometimes taken by fly; but a bait of worms, gentles, roe, or some other material, is commonly employed. The angler in these rivers usually stands on the shore while fishing; but in some instances he fishes from a punt, or small flat-bottomed boat, in which his chief occupation is to sit watching his float, and pulling in his line when a fish appears to be hooked. Among the apparatus of this order of deep-water fishers, a plummet and line is carried, in order to sound the depth of the river, which having ascertained, the angler puts his float upon the line, at that point which will allow the bait to trail slightly on, or just free of the bottom, while the float swims on the surface.

The first thing the bait-fisher has to learn is the art of baiting his hooks. Taking the hook in his right hand, and the bait between his fingers in the left, let him enter the hook at the head of the worm, and carry it through the animal to near the tail, covering the entire hook and its tying. The worm should be broken or mangled as little as possible; and the more lifelike it appears, the greater the probability of its proving an effectual lure. There must not, however, be too much spare worm left dangling from the hook, otherwise the fish will keep nibbling it away without biting at the bait bodily, and taking it into its mouth, the thing which the angler desires.

In throwing the line with bait, take care not to splash the water, but throw somewhat horizontally forward, so as to let the bait fall gently on the surface, and sink slowly in the water to the required depth. After sinking, the rod and line should be very slowly moved in a direction against the stream, or in some other way to give motion to the bait, which the fish perceiving to glide through the water, will hasten to seize upon. As fishes, however, are always on the outlook for floating garbage, one-half the dragging and twittering which bait-fishers generally employ is altogether useless, often positively hurtful, as scaring rather than alluring the objects of their capture.

Occasionally the angler will *feel* a nibble, but he must not be in a hurry to *strike*—that is, to draw the fish from the water. Perhaps it is no more than a nibble, and it is well to allow the fish time to get the hook in his mouth. If drawn too quickly, you may actually pull away the hook after it is half-gulped. Experience and dexterity are required in this ticklish part of the craft. As a general rule, do not strike till the line has been distinctly tugged; then strike by a slow side-motion at first, then a more quick jerk, so as to cause the hook to catch in the jaws of the animal. Supposing the fish to be hooked, do not draw it violently out of the water, as if in a transport of delight, but wind up part of your loose line if necessary, and holding up your rod, retire gradually backward, by which the fish may be landed on the shore. A good angler does not lay aside his rod to take a fish from the hook, unless it be of great size, requiring two hands; if small, hold the rod in the right hand while you catch the fish with the left; unhook it without mangling, place it in the basket, put on a new bait, and once more proceed to your sport.

The *gudgeon*, a fine large fish of the trout shape, affords a favourite amusement to anglers in the Lea, a river near London, and also in the Thames. Blaine thus speaks of this branch of angling: 'Fishing for gudgeons in the Thames is usually practised by means of a punt, which is fixed across the stream part of the river just above a tolerably sharp *scower*, running over a fine gravelly bottom, free from weeds, at depths varying from five to eight or ten feet. As the eddy is greater generally, and the water deeper in these scowers than in those of the Lea, so the tackle used is commonly somewhat stronger, and a fine gut-line is more frequently met with there than one of single hair. Fine tackle, however, in a good hand, is to be always preferred; and we have seen many hundred dozens of gudgeons taken in the sharpest currents of this river also with a single hair only for the two bottom links. Punt-fishing for gudgeon in the Thames is a delightful amusement, particularly to the luxurious angler who is not inclined to take much trouble. The scenery, the quietude, and safety from interruption, the cleanliness of the practice, where the bait is put on the hook by the attendant fisherman, and where even the prize it gains is removed by the same hand, all tend to make it epicurean in the extreme. But the thorough-bred fisher is soon tired with it after this method, for the very reason that there is actually too much luxury in it to constitute true sporting, which must of necessity present some labour to keep up the attention, and some difficulty to enhance the value of the prey. In the Thames, so many as fifty dozen of gudgeons have been taken in a day; but in the Lea seldom half that number are caught. Yet the Lea angler has the best scope for his sport, for he can commence it in March; whereas in all that part of the Thames within the liberties of the city of London, it must not be attempted until the beginning of June, at which time the gudgeons have spawned, and continue for some time afterwards inferior in point of their gastronomic worth. Gudgeon-fishing seems to have varied little from the ancient practice; and the angler who has aught of the antiquary about him, will be amused probably at the close parallel between the present method and the gudgeon-fishing of early times, as it is described by John Davers or John Dennys, Esq., for it is a disputed point to which of these worthies the *Secrets of Angling*, in which it is contained, owes its birth. Walton ascribes it to Davers, and gives the name at full length in the fifth edition of the *Complete Angler*:

"Loe, in a little boat where one doth stand,
That to a willow bough the while is tied,
And with a pole doth stir and raise the sand,
Whereat the gentle streame doth softly slide;
And then with slender line and rod in hand,
The eager bite not long he doth abide.
Well loaded is his line, his hooke but small,
A good big cork to bear the stream with all.

His bait the least red worme that may be found,
And at the bottome it doth alwayes lie;
Whereat the greedy gudgion bites so sound,
That hooke and all he swalloweth by and by.
See how he strikes, and pulls them up as round
As if new store the place did still supply;
And when the bit doth die, or bad doth prove,
Then to another place he doth remove."'

The *roach* is a thick fish, deep from the back to the belly; it inhabits the bottom of deep rivers or lakes, and is usually reckoned so incautious and silly as to be called the water-sheep; nevertheless, it is not taken without some degree of skill. It is angled for by means of bait sunk to within a few inches of the bottom. The fish may be attracted by throwing in some crumbs of bread. It is caught in the Thames some time after the end of August. The baits used are gentles, red paste, and boiled malt or wheat; one grain of the latter is sufficient. Great attention is required to strike quick when the bait is taken. Dace and tench are angled for much in the same manner. Carp is angled for

in stagnant waters from February to September, and the baits are worms, larvæ, grain, and pastes. The perch also inhabits dull waters, and is a short unshapely fish, soft in the flesh, and seldom worth cooking. It is so eager to bite, that little skill is required in pulling out a whole fry; the baits employed for it are worms, insects, and minnows.

Pike-fishing.

The pike is a voracious fish, and may very appropriately be termed the fresh-water shark; it does not confine itself to feed on worms, insects, fish, and frogs, but will devour water-rats and young ducks, and attack much larger animals. We are told, also, that on one occasion a snipe was found in the stomach of this voracious tyrant. All small fish are terrified at the approach of this marauder, which, if permitted, would soon clear a pond of all its finny tribes. 'Pike,' says Daniel, 'love a still, shady, and unfrequented water, with a sandy, clayey, or chalky bottom—arriving at a larger size in pools than rivers—and from May to the beginning of October they usually place themselves amongst or near flags, bulrushes, and water-docks, and particularly under the *Ranunculus aquaticus* when in flower, and which floats on the surface. They will sometimes be found in the termination of sharp currents. From March to the end of May, they resort to back waters that have direct communication with the main stream; as winter approaches, they retire into the deeps, under clay-banks, bushes impending over the water, stumps and roots of trees, piles of bridges and floodgates. They spawn in March or April, according to the coldness or warmth of the weather, quitting the rivers for the creeks and ditches communicating with them, and there dropping their ova in the grass and reeds; in ponds, they choose the weeds upon the shallows for depositing it; ducks and other wild-fowl eagerly devour the spawn, and by them it is transported to other waters. The appearance of the pike in ponds where none were ever put, has been deemed as extraordinary as its asserted longevity; it is, however, easily accounted for upon the well-known principles of the generation of fishes. If a heron has devoured their ova, and afterwards ejected them while feeding in one of these ponds, it is highly probable that they may be produced from this original, in the same way as the seeds of plants are known to be disseminated.

'Pike are in season from May to February—the female fish are to be preferred—are bold biters, afford the angler good sport, and may be fished for all the year; but the best months—especially for trolling—are February, before the weeds shoot, and October, when they have rotted down; the latter is to be preferred, as the pike are fattened by their feed during the summer; and from the lowness of the waters, their harbours are easily discovered.'

The same author thus describes the method of trolling for pike: 'For trolling, the rod should be twelve or fourteen feet long; but a strong top for this fishing, with a ring at the end for the line to run through, may be fitted to a fly or general rod; there should be one ring upon each joint to conduct the line, which is better than a greater number (and these rings must be set on straight, that it may run freely, so that no sudden check after the bait is taken prevent the pike from gorging it). The line should be of silk, with a swivel at the end to receive the armed wire or gimp, and at least thirty yards long, wound upon a winch or reel fixed to the but-end of the rod. Hooks for trolling, called dead gorges, and other sorts for trolling, snap, and trimmer, and fishing-needles, are to be bought at every shop where fishing-tackle is sold. In the choice of the first, let them not be too large, nor their temper injured by the lead on the shanks, nor the points stand too proud; and although usually sold on wire, it is recommended to cut off the wire about an inch from the lead, and with double silk, well waxed, fasten about a foot of good gimp to the wire, with a noose at the other end of the gimp large enough to admit the bait to pass through, to hang it upon the line. The best baits are gudgeons or dace of a middling size. Put the baiting-needle in at the mouth, and out at the middle of the tail, drawing the gimp and hook after it, fixing the point of the hook near the eye of the fish; tie the tail to the gimp, which will not only keep it in a proper position, but prevent the tail from catching against weeds and roots in the water. Thus baited, the hook is to be fastened to the line, and dropped gently in the water near the sides of the river, across the water, or where it is likely pike resort. Keep the bait in constant motion, sometimes letting it sink near the bottom, and gradually raising it. The angler need not make more than two or three trials in a place, for if a pike be there, he will within that time bite if he means to do so. When the bait is taken, if at a depth too great to see, it will easily be ascertained by the line being drawn tight, and by some resistance. Let the pike have what line he chooses; it will be soon known when he has reached his harbour by his not drawing more. Allow from five to ten minutes for his gorging the bait; wind up the line gently until the pike is seen—which he will permit though he has not gorged—should the bait be across his mouth, give more time; but if he has swallowed, manage him with a gentle hand, keeping him, however, from roots and stumps, which he will try to fasten the line upon; in clear water, veer out line until he is sufficiently tired, and a landing-net can be used; but by no means, however apparently exhausted, attempt to lift him out with the rod and line only; for the moment he quits the water, he will open his mouth, and from his own weight, tear the hook from his stomach; and the fish will be lost to the angler, although it must inevitably perish. In trolling, the bait should never be thrown too far: in small rivers, the opposite bank may be fished with ease; and the violence of its fall upon the water, in extensive throws, soon spoils the bait by rubbing off its scales, and alarms the pike instead of enticing him. Pike are to be allured by a large bait, but a small one is more certain to take them. Never suffer weeds to hang upon the hook or bait when recast into the water, and which cannot touch the surface too softly. Always prefer a rough wind, and when the stream is clear, for trolling; pike never bite in white water after rain or freshets. If a pike goes slowly up the stream after taking the bait, it is said to be a signal of a good fish.'

Mr Stoddart's methods of angling for pike here deserve notice: 'In rod-angling for pike, we adopt three methods—employing the gorge-tackle, the swivel-tackle, and the fly. Our gorge-hook is double brazed, and armed upon brass wire. A parr, or small trout inverted, is the usual bait. We insert the wire of our tackle through the fish, bringing the upper end of it out at the tail, and allowing the two barbs of the hook to protrude from its mouth. In angling, we both throw and drop the bait, as the nature of the water demands, moving it slowly towards the surface. When a pike seizes it, there is at first no perceptible tug; one feels as if he heard the shutting of a pair of jaws on the bait; and if you can manage to see your fish, you will observe him holding your trout by the middle, as if crushing the life out of it. Keep a tight line, but do not pull or strike. Too much resistance places your intended victim on his guard; a little, however, sharpens his appetite. After a few seconds, the pike will begin to move towards his den, still grasping your bait betwixt his teeth, and intending to bolt it immediately. Let out line with your hand from the reel; and now he is fixed, and darts off like a tiger, shaking his chain, and with open mouth tossing himself out of the water at thirty yards' distance—the worst is over, and he turns revengefully towards the shore; wind up—ha! he is out again, and again he makes for the shallows; but the monster is exhausted,

and moves heavily; lead him with caution to the edge, lay down your rod, and lift him upon the bank. In order to disengage your hook from the entrails of this formidable fish, the gills should be forced open, and a knife introduced for the purpose, taking care previously to thrust it through the spine-bone of your victim, and so prevent the possibility of your catching a Tartar. Unfasten your hook from the wire before drawing the latter through the mouth of the pike, as otherwise it is again apt to catch among the teeth, from which it may be somewhat difficult to extricate it, without incurring a few scratches.

'Should a fish, after having bitten, abandon your gorge-hook, try him with a running-bait upon swivels, and let this be a fresh trout of a smaller size than your other, and fixed upon a gimp-tackle with the tail downwards, as in minnow-fishing. See that it spins judiciously; and when the pike rises, let him turn with the bait before you strike. River-pike, it may be remarked, seldom play so well as those in lochs. They push generally below the banks instead of striking across, and look out for old stumps upon which to entangle and break your line. One ought, therefore, to make quick sport with such rascals—running them down upon level banks in a twinkling, and before they are able to get under-way.

'The third method of angling for pike is with the fly—a kind of fishing not much in use, but still on some waters very deadly. The pike-fly should be large and gaudy, fabricated of divers feathers and tinsels, to resemble the king-fisher or a huge dragon-fly. Use it in a strong warm wind, upon water from six to two feet deep, and near weeds. You will kill with it fish of various sizes, from ten inches in length and upwards: very heavy ones, however, refuse to take it, on account, probably, of the exertion necessary in order to come to the surface. We have always noticed that the biggest pike are caught during close sultry weather with a ground bait, and at those times when trout refuse food altogether; also at night, with set lines, in the summer months, when they leave the weeds and bulrushes in quest of food.

'Although the pike is often nice and suspicious in places where trout abound, still, when provoked, he becomes bold and unwary, treating your presence as no constraint upon his temper and appetites. He will follow the bait to your very feet, and should it escape him, will retire a yard or two, waiting eagerly for its reappearance. When angry, he erects his fins in a remarkable manner, as the lion doth his mane, or the porcupine his quills; moreover, the pike appears careless of pain, if indeed fishes in general feel it to any great degree. We have actually landed one of these fish, cooped him alive in our creel, and when by some negligence of ours he made his escape into the water, have succeeded a second time in securing him. On another occasion, we remember having a part of our tackle, consisting of a large double gorge-hook dressed upon brass wire, carried off by a pike; and yet, upon renewing it, the aggressor returned to the charge, and was taken. The former hook we discovered gorged by him in such a manner as must, we thought, not only have suffocated any other animal, but done so by the medium of the most exquisite internal agony.

'Great injury has of late years been done by the transference of the pike to many of our best trouting lochs, where a single individual has been known to consume nearly its own weight of fish daily. This was the case on Loch Turit, near Crieff, where the trout, formerly abundant, are now greatly reduced by the hostile and merciless depredations of their natural enemy. The pike at table is reckoned by some a coarse dry fish, and so in general they are; yet to our knowledge, in certain lochs, for instance that of the Lowes in Selkirkshire, they almost rival the turbot, and should be cooked somewhat in a similar manner. They are none the worse for being kept a few days, especially if of any size. A good eating pike ought to weigh at least from five to twelve pounds—the smaller ones being without exception bad.'

Trout-fishing.

The trout is of different species and varieties, as the common trout, the gillaroo or gizzard trout of Ireland, the bull trout, and the salmon trout. The shape is handsome; the flesh firm and sweet, and coloured pink or white, according to species and feeding-ground; and the weight varies from a quarter of a pound to eight or ten pounds. In one or other of its varieties, the trout is a universally known fish in temperate climates; its favourite haunts are clear running rivers; and there, both in England and Scotland, it affords a favourite object of sport to the skilful angler. Sometimes bait is employed, but the fly is more common. In some cases, the bait and fly must be tried alternately in one day, as the fish is capricious, and requires to be tempted in all kinds of ways. The season most favourable for trout-fishing is spring and early summer. Mr Colquhoun, in his interesting work, entitled *The Moor and the Loch*, gives a great deal of information on both loch and river fishing. *Fishing with Bait.*—'Trout,' says Blaine, 'begin to take a bait on or near the ground early in the year, and before March, will readily take most bottom baits all day long in favourable weather; but as the summer advances, it is only very early or very late in the day that they will take a bait near the ground, they being at the intermediate hours more disposed to rise to the surface for winged insects. In March and April, use the worm in the forenoon, and a fly or minnow, according to the state of the water, the rest of the day, in the swiftest and sharpest currents, provided the day be warm and bright, and in the deeps early and late; but if the water be discoloured, or very thick, try the gravelly shallows near the sides and tails of streams with a worm only, to run on the bottom with one large shot a foot at least from it. When there is a small *fresh*, or the water is clearing off, and is of a dark-brownish colour, first use the worm, which should be a well-scoured brandling, cast in as a fly at the head of the stream, and move it gently towards you, still letting it go down with the current, so as to keep it a little under water: the line should be rather short, with no lead upon it, and the hook fine; then try the minnow, and as the water clears, the artificial flies should be tried. In fishing for trout with the worm, use running-tackle, and employ a strong line, but let its strength consist in the excellence of its material rather than its bulk, to which end the hook should be small, the gut fine, the shotting fine also, and let the whippings be well concealed, for in bright water trout are singularly wary and suspicious.

A short line and quick striking are recommended by Mr Stoddart, who says the line 'ought always to be kept at its full stretch, and moved in a half-circle with the angler. It requires some degree of perception to know the exact instant when the fish first seizes your bait; it does so with such softness, and with no likeness of a tug, as one is apt to imagine; nay, it merely closes its jaws upon the hook, as a gaping oyster would do upon one's finger. Then is your opportunity for striking; if you neglect it, you allow the trout its more leisurely process of nibbling, and its chances of escape. In striking with the short line, do it sharply, and never against the current, but rather with it, in a diagonal direction, and not too high. The reason of this advice is obvious, for all fish feed with their heads pointing up the stream—kindly giving you the choice of pulling the hook into or out of their mouths; the latter of which purposes you accomplish, to a dead certainty, by striking against the current. This whip-jack manner of bait-fishing is very deadly with an experienced hand. The long-line anglers make nothing of their method comparatively; and yet, among clear waters, and where fish are few, or bite shyly,

patience and a long line will carry the day. Remarkably fine gut ought to be used by all ground-anglers, whatever be the practice. Trout are a suspicious, distrustful set, and three in general slink off for one that nibbles; terrified, no doubt, by those singular accompaniments of your worm, a line and hook.

'To all bait-fishers, Scotland affords excellent sport; her rivers run so strongly, and are maintained by so many sources in the shape of mountain burns. These romantic streamlets abound in trout; every stone shelters its inhabitant, and the meanest pool is peopled with numbers. Burn-fish, however, are generally of a small size; they seldom exceed a pound in weight, except in the spawning season, when larger ones ascend from broader streams or lochs at a distance. Still, the taking of them is a pleasant pastime, especially when they bite eagerly at your worm, as they do during rain and in discoloured water. At such times, you have only to drop your bait without art, and the fish will manage its own ruin.'

The same enthusiastic brother of the rod next proceeds to treat of minnow-fishing, which he says is by far the pleasantest mode of capturing trout, next to angling with the fly. 'If you wish to engage in this pleasant sport, provide your minnows by means of a small drag-net or hook. Fish in rapid streams, also in deep discoloured pools, and during a smart curl. Manage the minnow as you would your fly, throwing it down and across as far as you are able; bring it towards you about six inches or more below the surface, spinning rapidly by the aid of several swivels. When a fish rises, give him time before you strike; let him turn and gorge the bait, then strike sharply, and he is yours.

'Trout seize a minnow by the middle or near the head, and you generally hook them on the upper hooks. In rivers where numbers of minnows are found, you must angle with the very smallest, not above two inches in length, and use a proportionate tackle. The trout in such waters love delicate tidbits, and are absurdly nice in their feeding. Artificial minnows are frequently used by anglers, and with considerable success.'

'Trolling with parr for large trout,' he continues, 'is a glorious pastime, especially on a Highland loch, circled with mountain scenery—the craft of nature by incantation wrought, when the morning-stars sang together. It needs intellect to enjoy it well, and a poet's heart to know its luxury. Take with you some choice and idle spirit, a rower he must be, that can manage your airy shallop as the winds do a weathercock—can chant a ballad of yore, of ladye and chieftain, and pranksome elf and kelpie wild—can speak to the echoes and to yourself, cheering you with wit and wisdom, and admiring your science and skill, and the gorgeous fish you are playing, twenty fathom off, with a strong and steady hand, your heart "high fluttering the while, like woman's when she loves."

'Tackle for trolling should be dressed upon tried gimp. Bait as you do with a minnow: use a strong rod, heavy lead, and a long line of oiled cord wound upon an easy reel. Choose a sunny day, with a stiffish breeze, and troll near, but not amongst the weediest parts of the loch. Plant yourself at the boat stern, and get rowed gently at the rate of three miles an hour, letting out from twenty to thirty yards of line betwixt you and your bait. Trout from six to nine pounds' weight cause the best sport when hooked; a larger one seldom leaps or makes any violent exertion to escape; he swims sullenly, and at ease, regarding the angler with a sort of sovereign contempt. You must row after him, and turn him if you can before he gets among weeds; never slack your line for an instant, and look well about you. Land as soon as you are able, and play him from the shore. Your companion will assist you at the death.

'So much for the different kinds of bait-fishing practised in Scotland. We esteem it folly to talk of the less popular baits used by the *virtuosi*—of frogs, grubs, and leeches, water-rats, and mice—all of which animals trout will devour. It might be asked, may fish not be taken with anything? They have been known to swallow money, rings, and many other glittering marvels; nevertheless they seem to have no pleasure in snapping at the bait of the unskilful angler, and refuse to die under his hands.' Parr-tail, and a small fish called in Scotland the beardie, make excellent spinning-bait, and are frequently used with deadly effect.

Fishing with Fly.—This, after all, is the true angling, all other efforts at taking fish being either somewhat childish or murderous. A long flexible rod, fine lines, and appropriate flies, are the necessary equipment; and the best time for making the attempt is on a dark lowering day, at anyrate not in bright sunshine. If the moon has shone brightly the previous night, it will have prevented the trouts from feeding freely, and they will accordingly bite more readily when tempted with the artificial fly. Great skill and nicety are required in throwing the fly-line. Mr Stoddart gives the following directions how to proceed:

'Your rod and tackle being ready, the wind in your favour down the river, draw out with your left hand a few yards of line from your reel, dip the top of your rod in the water, and with a rapid jerk you will lengthen as you wish that part you intend for throwing. A thirteen-foot wand will cast from six to seven fathoms of line. With a large double-handed rod you may manage a much greater length. Always, if you can, angle from a distance. Trout see you when you least imagine, and skulk off without your notice. Noise they care little about; you may talk and stamp like a madman without frightening them, but give them a glimpse of your person, and they won't stay to take another. Some ichthyologists attribute to them an acute sense of hearing: this we are disposed to question; for how happens it that the most obstreperous rattling of stones, when wading, causes no alarm, although conveyed to them through the medium of water, a good conductor of sounds? We remember angling one still night by St Mary's Loch, when our movements were heard distinctly by some shepherds at the distance of a mile, and yet the fish rose eagerly at our very feet, following our fly to the shallowest parts of the margin—a fact which, if it does not prove obtusity of hearing on the part of the fish, at anyrate renders it a matter of little consequence to the angler.

'It requires some art to throw a long line. The beginner should commence with a short one, and without flies, lengthening it gradually as he improves. The best method of casting is to bring the rod slowly over the right or left shoulder, and with a turn of the wrist, make the line circle behind you, then, after a pause, fetch it forward again in the same manner, and your flies will descend softly upon the water. All jerks are apt to whip off your hooks or crack your gut. A fly-fisher may use two, three, or four flies on his casts, according to pleasure. When angling with small hooks, we adopt the medium number. Large ones ought to be fished with in pairs and well separated. In throwing the cast, the lowermost or trail-fly should be made to alight foremost; its fall ought to be almost imperceptible; it should come down on the water like a gossamer, followed by the droppers. The moment a fly touches the surface, it is ten times more apt to raise a fish than during the act of drawing it along. At no time are we stanch advocates for the system of leading our hooks either against or across a stream; our method is rather to shake them over it for a moment, and then repeat the throw. A trout will discover your fly at the distance of several yards, if feeding, and will dart at it like lightning. Always, if you can, fish with the wind, and do not concern yourself, as some do, from what quarter it comes. In spring, no doubt, a south-west breeze is preferable to all others; yet we have seen even easterly winds not the worst on many waters, especially during

summer months, when the natural fly is apt to become over-plenty.

'Trout will sometimes take in the most unlikely weathers, so that the angler should not despair at any time. Hunger causes them to feed at least once in the twenty-four hours, and generally much oftener. If the wind blows down the river, commence at the pool head, and fish every inch of good water; you may pass over the very rough and very shallow parts, also those which are absolutely dead calm and clear, unless you see fish rising in them, when, should your tackle be light, there is no harm in taking a throw or two. Dead water, however, when rippled or discoloured, may be angled in with great success. When you raise a good trout, strike slowly, or hardly at all; only continue the motion of your hand without slacking it; the fish, if large, will hook itself. Small trout and parr may be whipped in with rapidity: it is folly to play or use ceremony with such trifles. Should the fish miss your fly altogether, give him another chance, and a third, if that will not do; a touch of your barb, however, will sharpen his wits, so as to prevent him from again rising. He prefers flies without stings. When you hook a trout, if you can, turn his head with the stream, and take him rapidly down. Thus you will exhaust him in the shortest time; whereas, by hauling against the current, you allow him to swim freely in his natural direction, and also exert three times more strength upon your tackle than is really needful. A good-sized fish, handled in this foolish manner, can never be taken; it is impossible to tire him out, and the strongest line will give way to his resistance. When your victim is exhausted, draw him gently ashore upon the nearest channel or most level part of the margin. He will come in sideways, and generally lie motionless for a few seconds, during which time you will be able to run forward and seize him. Beware of catching hold of your line until he is properly banked. Many a famous trout have we seen lost by this inadvertence on the part of anglers, who think so to save time and labour. One should remember how the spring of the rod is thus removed, and how there remains no proper curb to the strength of the fish, which easily breaks a single gut, or tears itself from a sharp hook, and wishes the astonished angler better sport further on.'

The practice of double-rod fly-fishing for trout or for salmon, is a murderous kind of sport, and should be prohibited by law. A line stretched between two rods, and hung with flies, is taken down the stream by two individuals on its opposite sides, so that every part of the water is gone over, and every feeding trout raised. By this plan, large numbers are caught, but many also are wounded, and escape, to pine away for months at the bottom, unable either to feed or spawn.

Salmon-fishing.

This may be described as a gigantic trout-fishing, the principle of alluring and capturing being the same, but all the tackle requiring to be stronger, and a greater degree of physical power being necessarily called into operation. The salmon has a peculiar habit, very likely to upset the calculations of beginners: it consists of the ugly practice of running off at a violent speed as soon as he feels himself hooked, darting up the stream, throwing himself several times out of the water, and generally in the end hastening into some sheltered haunt under the banks where he expects to be safe. Great tact is necessary on these occasions, first to give line, and then to keep him from burying himself in these unapproachable nooks.

With respect to the minutiæ of the art, both in throwing and striking, the recommendations of Mr Younger of St Boswell's are well worthy of attention. 'I recommend a beginner,' says he, 'to practise throwing the line on a broad smooth pool, where he can see that it is delivered out properly, and falls lightly, without splashing. In such a case, the practitioner will perceive something which he cannot easily account for—and that is, that after he has even attained a great degree of perfection in the art, he will not be able to distinguish how it happens that in one throw his long line will proceed direct out, his fly alighting first on the water; in another throw the middle of his line will fall first, while the further part, still obedient to the general impulse, will proceed out the full length, the fly falling the last on the surface. This last throw is not so good as the former; for this reason, that the main current having caught the middle of his line first, carries it too quickly down, leaving the fly lagging, to form an awkward curve, as, before it comes over above the fish, the fly should lie on the water, so as to have the appearance of plying at an angle against the current. And the angler should so manage his rod, that while he lets his line float round at its full length, yet to cause his fly to come as slowly as possible over the main spot. In this case the salmon will sometimes rise at once, rather before you expect him, but more generally will follow the fly to the eddy, or edge of the deep, where, if on examination he feel disposed to seize the hook, he has it before you perceive a head, fin, or tail above the surface. Indeed, before you perceive the web of his tail, he generally has the hook in his jaw a foot below water, as in descending he goes, like other divers, head-foremost.'

Having managed to place the fly over the desired spot, our authority continues: 'He will make no perceptible motion to keep his fly on the surface (except on a sluggish pool), but let it sink a little, depending on feeling rather than on sight; and though apparently keeping no pull on his line, yet all the while able to detect the touch of a minnow. On a *boil*, or other appearance of a fish, he pulls up his line, not twitchingly but actively, steps a yard or two back, rests a minute to let the fish resume his lair and attention, and perhaps feels inclined to alter his fly, before he annoy and disgust or alarm his fish, to a shade darker or a size smaller, when he will most probably come up and seize it in earnest. Should he not rise again, or rise and pass it thrice, leave him quietly alone for the present, and return to try him some time afterwards. On taking the fly, the fish means to return with it to his precise select *spot* of lair, on rock, stone, or gravel, at the bottom; and the fine angler, holding him gently, often in the first instance allows him to do so, but soon, too surely feeling his awkward predicament, he bolts off, "indignant of the guile." Then is the time when the fisher is attentive. With the but-end of his rod resting on his thigh or groin, he keeps the top nearly erect, never allowing it to fall below the proper angle of forty-five degrees, as relative to the situation of the fish, as in this position the elasticity of the rod never allows the line to slacken in the least degree for a single instant, however the fish may shake, flounce, jerk, or plunge. With two or three fingers and the thumb of his left hand, the angler holds his rod while the wheel-line runs out, regulated by the first or first and second fingers, relieved or assisted, as occasion may suggest, by the right hand, when it can be spared from its necessary occupation of rolling up the wheel-line, as the fish settles a little or returns inwards. In this manner the fish is allowed to run right out, up, down, or across, as he may choose. But if in an outright dash of thirty or fifty yards aslant, ending in an outward-bound fling above water, the inexperienced angler should feel flustered, which he is very likely to do, and by some involuntary twitch of the running line let the top of his rod be pulled down to a level with his own head, then the tug of the last plunge will assuredly break his hook or line, or tear the hook from the mouth of the fish; or, what is as bad, a sudden jerk or turn of the fish will give the line a momentary slackening, when the hook's hold, already so strained as to have widened its incision, will fall out, and your fish is gone for ever.'

Now is the critical moment for the salmon-fisher, who must keep up his rod and give line. 'The fish will then,'

continues John, 'allow himself to be led at ease to the angler's side of the river, like a bridegroom to the altar, when, on finding the water shallowing, he will again make another desperate effort, probably a new dash into the middle current; but too much exhausted to resist the still continued pull upon him, he will soon again fall into the shallow, where, on a sight of his enemy, he is again alarmed into a new effort, and again exhausted by turning his outward-bound head down with the water, again and again, and again, as if the parties were in the amusement of forming circles, until his own last efforts to keep swimming are made subservient to the cautious angler in moving him by degrees into the shallow, where, half dry, he must, like all the strong, at last yield to his fate, and fall panting on his side, while the line rolled up to within rod-length, which is to be held with its top landwards, without slackening, and the fisher seizing him with the forefinger and thumb of his right hand across by the root of the tail—which is by far the surest method of seizure—lifts, or rather slides him out head-foremost over gravel and grass, and in mercy fells him with a blow on the back of the neck.

'After going through this process with a twenty-two pounder—and the process would be the same with a forty-four—the writer can aver, that he does not conceive that from the moment he has hooked such until he was laid on the grass, he ever for an instant had three ounces of more or less pull on the fish; for in all circumstances of run, regularity of pull is the sure test of true skill and final success. Indeed, I have seen many a fine fish laid on the dry gravel when the hold of the hook in the lip of his mouth was so slight as to be smaller than the steel of the hook—so much for equal pull and cautious management in the run. And, in short, a man is never a master-angler so long as a desire to have his hooked fish to land excites in his feelings the least agitation, as the matter should be managed with that cool philosophical ease of mind which is alike above the paltry calculations of loss and gain and the common ridicule, which often tends to stir up a degree of childish fretfulness. This perfect nonchalance is absolutely necessary to first-rate excellence and ultimate success.' Though it may be contrary to the usually established custom, and appear cruel to a sensitive mind, still we have been told that it is a mistake to kill either salmon or trout, as they are by that means the more apt to become soft and flabby in the flesh.

Leistering is the name usually given to a murderous kind of sport pursued by salmon-fishers in Scotland. Armed with *leisters*, or spears with three-barbed prongs, a set of fishers proceed to the river's bank, and there attract the fish by the glare of torches held over the water by members of the party. When a salmon is discovered, one selects it as his prey, and by a cool but rapid blow transfixes it with his spear. In many cases, the fish cannot be secured or landed without plunging into the water; but this usually forms no obstacle, and several men may be seen floundering in the depths of the stream while shouts and confusion prevail among the spectators on the banks. Sir Walter Scott, in his novel of *Guy Mannering*, has presented a vivid picture of this species of sport, which is still pursued on the Tweed and its tributaries, but mostly by parties of rude marauders who are regardless of law, and kill vast numbers of fish during 'close time,' or when the rivers are legally shut. As the law at present stands, all salmon-fisheries north of the Tweed close on the 14th of September; Tweed net-fishing on the 1st of October; and Tweed rod-fishing on the 14th of October. The fisheries north of the Tweed open on the 1st of February; and those of the Tweed, both for rod and net, on the 1st of March. (See FISHERIES.)

The Parr.

The parr is a small fish, which is found in great abundance in almost all rivers which are clear, and have a free communication with the sea. It varies in size, of course, according to its age, but seldom reaches a greater length than six inches, and is usually found below that magnitude. It is silvery in appearance, and marked by peculiar bluish bars or marks along the body; while a more nicely forked tail, and one regular row of scarlet spots along the sides in place of two or three, aid further in distinguishing the parr from the trout, the fish which it most resembles.

Of the actual character of the parr, whether it is an independent species or the fry of salmon, there has been a long-continued controversy. Many naturalists were inclined to hold it as a kind of mule—a creature betwixt the trout and salmon breeds. The dispute, however, may be said to have been terminated by Mr Shaw of Drumlanrig, whose lengthened and ably conducted experiments have established the parr to be the natural produce or fry of the salmon. In a memoir communicated to the Royal Society of Edinburgh, Mr Shaw mentions that his first experiment on the subject consisted in the removal of a number of parrs from their native stream to a pond, when he found that all of them assumed the perfect appearance of *salmon fry* or *smolts*, at the end of periods of time proportioned to their bulk when placed in the pond. He also satisfied himself that the change from the state of parr to that of smolt, which is marked by the appearance of a covering of silvery scales over the blue bars, always takes place at the age of *two years;* and that then, for the first time, the metamorphosed fry take their downward departure for the sea.

But it was objected to these experiments, that Mr Shaw might have mistaken young salmon for parrs in the first instance, so rendering his conclusions of no weight. To settle all disputes, he began his experiments with the *ova* or *eggs* of the salmon, first constructing ponds for their reception. These ponds, three in number, he protected by falls, pipes, and gratings, in such a way as to seclude them in a perfect manner from all interference on the part of any other fishes whatsoever. Having provided a proper net, Mr Shaw was successful in capturing a pair of adult salmon, male and female, while engaged in depositing their spawn. By expressing a portion of the ova from the female, and of the milt from her companion, he had it in his power to transfer fertilised ova to his ponds on the 27th of January 1837. 'On the 21st of March, fifty-four days afterwards, the embryo fish were visible to the naked eye. On the 7th of May, they had burst the envelope, and were to be found among the shingle of the stream. It is this brood which I have now had an opportunity of watching continuously for a length of time.

'At the age of four months (7th September), the characteristic marks of the *parr* were clearly developed. Two months later (six months old, 7th November), an accession both of size and strength was apparent; and on comparing the pond specimens with those of the river, no marked difference was perceptible. The average length at this time was three inches.' Mr Shaw goes on (in a paper read to the Royal Society) to describe a number of specimens, at different ages, of which we give four.

'Number six is a specimen from pond number one, of the age of nine months, taken in the middle of February 1838. It exhibits little or no particular accession of size or condition to that of number five, but may serve to shew the general appearance of the several broods of the young salmon in my possession at the age of nine months.

'Number seven is a specimen twelve months old, taken from pond number one, on the 10th May 1838. It is much improved in condition, as well as in external appearance, in comparison to that taken in February, and has exchanged its dusky autumnal and winter coating for that which may be called its summer dress. It measures about three and three-quarter inches in

length, and is denominated, along with those of a corresponding age and size in the river, the *May Parr*. Immediately after the migration of the two-year-old parr—which the latter always effect about the beginning of May, under the name of salmon-fry—there is no other parr, besides such as have been recently hatched, to be found in the river, save those which correspond with this specimen, which is the *Pink* of the river Hodder alluded to by Mr Yarrell. As the summer advances, they increase in size, and are actually the little fish which afford the angler in salmon-rivers so much light amusement with the rod during the months of August, September, and October. They remain over the second winter in the river, during which period the males shed their milt, and are found continuing their kind along with the female adult salmon, although still bearing all the external markings of the parr, as I shall afterwards more particularly mention.

'Number eight is a specimen eighteen months old, taken from pond number one, on the 14th November 1838. It measures six inches in length, and has now attained that stage when all the external characteristic markings of the parr are strikingly developed, and, in point of health and condition, cannot be exceeded by any taken from the river. All the males, at the age of eighteen months, of the several broods in my possession, last autumn (1838) attained a most important corroborative stage—namely, that of shewing a breeding state, by having matured the milt, which could be made to flow freely from their bodies by the slightest pressure of the hand. The females of the same broods, however, although in equal health and condition, did not exhibit a corresponding appearance in regard to the maturing of roe. The male and female parrs in the river, of a similar age, are found respectively in precisely a corresponding state, which may surely be admitted as important evidence in support of the fact, that all these individuals are, in truth, specifically the same.

'Number nine is a specimen two years old, taken from pond number one on the 20th May 1839, *after having assumed the migratory dress*. The commencement of the change, which was perfected by the whole of the broods about the same time, was first observable about the middle of the previous April, by the caudal, pectoral, and dorsal fins assuming a dusky margin, while at the same time the whole of the fish exhibited symptoms of a silvery exterior, as well as an increased elegance of form. The specimen in question, so recently a parr, exhibits a very perfect example of the salmon fry or smolt.'*

Subsequent observation and experiment have abundantly confirmed Mr Shaw's conclusions as to the parr being the young of the salmon, and that it becomes transformed into the salmon fry or smolt. But it is still an unsettled point how long the parr state continues. Mr Shaw admits that individuals assume the migratory or smolt dress at the age of twelve months. His opponents maintain that this is the rule, and that cases in which the transformation does not take place till the beginning of the third year are exceptional, the natural development being interfered with in some way. The state of confinement in which Mr Shaw's broods were kept, is thought sufficient to account for their slow development. Experiments on a large scale have since been carried on at Stormontfield, near Perth, with a view to determine this question. In the beginning of June 1855, a brood then fourteen months old, many of which had quite recently undergone a transformation in appearance, were allowed their liberty; when about half availed themselves of it, the rest remaining in the pond. Some thousand of those that took to the river were marked, and several of these were caught in the river in July and August of the same year, having migrated to the sea, and returned as grilse of from three to seven pound. The biennial period, then, is not so absolute as Mr Shaw would make it; still the chief authorities seem to think it much nearer the truth than the annual.

* One or two of each of the three broods assumed the migratory or smolt dress at the age of twelve months.

The smolt, on entering the sea, grows with surprising rapidity; according to Mr Young, its stay seldom exceeds two or three months, and during that time it expands from a few ounces to as many pounds. But on this point, too, there are conflicting opinions, some holding that the smolt that enters the sea one summer, does not appear in the river as a grilse till the summer following.

An important point in the natural history of the salmon is the tendency to return to the river in which they were bred. It is no doubt carrying the idea too far to maintain that they always do so; and the cause, instead of the unerring instinct to which it has been ascribed, is perhaps to be found simply in the distance between the mouths of rivers. In the main, however, it may be held as a fact, and one that affords inducement to protect the fish in the spawning season, and also to increase their numbers by artificial breeding.

In Mr Young's experiments in the river Shin, he found that grilse caught in spring while descending to the sea after spawning, and marked, returned within three or four months, as full-formed salmon, having increased from four pounds to nine or fourteen pounds in weight. The adult fish, after spawning, are called *kelts;* the male fish is sometimes also called a *kipper;* and the female, a *shedder* or *baggit*.

Of late years, attention has been turned to the importance of stocking rivers with fish artificially, by means of breeding-ponds, where the eggs or spawn and the young fish are protected for a time from the many accidents and enemies to which they are exposed in the earlier stages. New and profitable kinds of fish are also introduced into rivers in this way. In France and Germany, the practice is said to be attended with marked success, and is coming to be looked upon as a new branch of national economy, under the name of *pisciculture*. Efforts of the same kind have been made in Scotland, as at Stormontfield, near Perth; though in the case of a migratory fish like the salmon, the effect is extremely difficult to ascertain.

Mr Boyd has recommended the propriety of securing a few thousands of the fry, just as they are about to assume their migratory dress, and transmitting them to the rivers of Australia and Tasmania. By this means, the inhabitants of those countries would be supplied with this valuable fish.

FISHPONDS.

Artificial ponds for the rearing of fish and supplying them when wanted for the table, were common in ancient times. The luxurious Romans possessed such preserves, and we learn that one belonging to Lucullus sold after his decease for upwards of £24,000. Comparatively little has been done in modern times in the way of establishing artificial ponds, and those which exist are chiefly to be found in noblemen's preserves. Yet artificial fishponds may, with little or no trouble, be made to yield a large and regular supply of fish, and may be constructed at a most insignificant expense in any piece of low-lying waste ground intersected by a rivulet of pure water.

The fish most suitable for ponds are trout, carp, dace, roach, bream, tench, perch, and minnows. Eels also thrive in ponds; and what has frequently been a matter of surprise, these animals sometimes find their way to ponds of their own accord, without actual transfer. It is extremely probable that the spawn or young of eels and other fish is gobbled up and vented by birds in appropriate localities; there is at least no other rational means of accounting for the spontaneous stocking of remote fishponds and lakes.

The size of a pond may be from one to twenty acres; but a piece of water of from two to three acres is

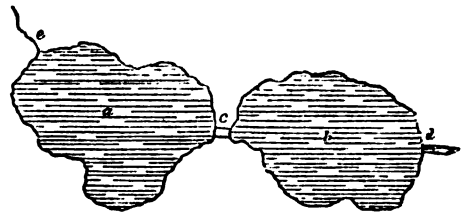
considered the most convenient dimensions. Of whatever size, the pond must not be overstocked, and it must not be left too long unfished. Fishponds, to be on the most effective scale, should be in a series of two or three, the water running from the one to the other. This will allow means for periodical cleaning, if required, and for having a choice of fish. Some remarks of Daniel may here be introduced:—'In ponds so situated as to have communication with each other, never put into the upper of them either a pike, a bream, or a roach; the spawn will get through the gratings, and by that means all the lower ponds will unexpectedly swarm with them. The pike will destroy the fry of the carp and tench, and the two latter will consume all the food which should be the subsistence of both parents and progeny. Pike, bream, and roach should therefore on no account be ever put into the first or highest of a succession of ponds.' He continues: 'Some have recommended, in raising carp, to have three ponds: one wherein the fish are to spawn—which is mostly from May to July—and in which they should continue during the summer and ensuing winter. A second for the convenience of nursing up the young fry, into which they should be put at the end of March, or early in April following, choosing a calm but not sunny day for their removal, and being careful to prevent their being destroyed when coming to the sides of their new habitation. In this pond they may remain two years, and become four, five, or six inches long. The third or main pond is for the reception of those that are so grown as to measure a foot or more in length, including their heads and tails.'

The proportions advised for the stocking these different ponds are—for the first sort, per acre, 'three or four male, and six or eight female carps; those of five, six, or seven years old, in good health, with full scale, and fine full eyes and a long body, without any blemish or wound,' are to be preferred. The pond must be previously cleaned of all sorts of voracious fishes and other animals, as 'perch, pike, eels, and trout; the water-beetle, and also the frogs; the newts or lizards;' have a warm and open exposure with soft water, and all kinds of water-fowl kept from it. For the nursing-pond, a thousand or twelve hundred carp may be not more than sufficient for an acre; and for the main pond, one to every square of fifteen feet is the allowed space, as their growth depends greatly on the room they enjoy and the quantity of food.' As to tench, which are not generally held in the estimation they deserve, Mr Yarrell recommends that large and fine fish be chosen as breeders, as being the most certain mode of obtaining sizeable fish for table in the shortest space of time. Two males to one female, or not less than three to two, should be the proportion of the sexes; and from the pond, which is found by experiment favourable for breeding, the small fish should be in part withdrawn from time to time, and deposited elsewhere, to afford more accommodation for all.

Our friend Mr Stoddart likewise treats of fishponds, but mainly in reference to Scotland, where the fish must be of the hardier kinds—perch, pike, and trout. In either case, the transfer of the fish to the ponds may be made with little difficulty. On being caught with a hoop-net, place them in large jars of water, and cart them to their new habitation; if this be inconvenient, they may be carried in wet moss or straw. All fish bear carriage best in winter, and better during the night than during the day.

'Ponds intended solely for perch do not require to be made large; they should slope gradually down towards the middle from a depth of six inches to one of five or six feet. Water-weeds ought not to be greatly encouraged. A series or chain of small basins, at different elevations, is preferable to a single large reservoir for this fish. These basins should be connected by a sluice and floodgate, so that one may be readily emptied into another for the mutual convenience of cleaning and repairing. Also the uppermost ought to be shallower than those below, and more exposed to the sun, so as to serve for a nursery and breeding-pond. Bream live well with perch in a warm situation; they are not, however, obtained readily in Scotland. Perch-ponds should be let off and paved with channel stones every four or five years; many allow them to remain fallow for some months, and others sow them with grass and oats—a conceit laboriously encouraged by theoretical writers of bygone days.'

The following engraving represents a pair of perch-ponds: *a* is the upper or breeding pond; *b*, the lower

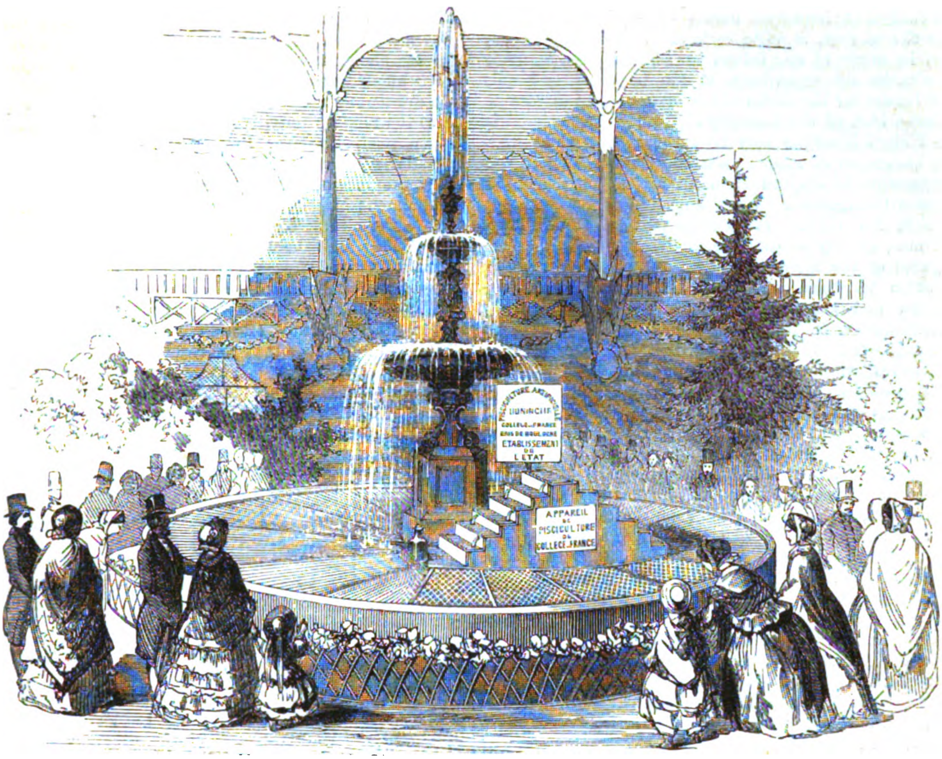


pond; *c*, a covered sluice with movable gratings; *d*, the sluice with outlet; and *e*, the small feeder.

'The pike-pond,' proceeds our authority, 'if for breeding and fattening to some extent, ought to be large, covering from eight to twenty acres; its mean depth six or seven feet. One end, however, should be much shallower, and sown with bulrushes or other water-plants. Previous to stocking it with this fish, a sub-stock of perch or trout should by all means be introduced; otherwise, without a great supply of such sustenance, pike will not only become thin and ill-tasted, but quarrel and devour each other. To facilitate a steady supply of perch, small tanks should be constructed alongside of the leading preserve, with connecting sluices and flood-gates, so as to expel, when necessary, a shoal of live food.'

Our author next treats of trout-ponds: 'Choose from six to twenty acres, less or more of an oval shape, but indented with small bays. Cast a long trench through the middle, from head to foot, noticing that you can readily divert along it the stream just mentioned, which stream is intended as a spawning-place, seeing that trout never shed their roe in dead water. Let this trench deepen gradually as the ground descends; so that at the intended foot of the pond it should sink nearly three yards, while the upper part thereof is kept shallow. Dig from either side of your trench, keeping its slope and level until within four fathoms of the intended margin of the fishpond. When this is done, turn your attention to what is called the dam-head, at the outlet or lowest part of the pond. From it continue your trench for a short distance in the form of a paved sluice. Build stones, grass-sods, and clay, along the bank on each side, if needful, and drive in a few piles to strengthen it. Then set a floodgate at the outlet, and another to serve as a check in case of accident, three yards further down, where your paved sluice terminates. A few cart-loads of coarse channel, not from the sea, ought to be emptied over the earthy parts of your pond, which otherwise are apt to get covered with weeds, or else to encourage eels, the marked enemies of trout in all stages. After this is done, let loose your stream, and form your preserve, introducing trout of about six inches in length, eight or ten to every acre. Raise also at the head a small nursery of minnows, connecting it by distinct sluices both with the pond and its feeder. These are favourite food of trout, and fatten them at a quick rate.'

We have read with great pleasure *The Practical Angler*, a little book full of really useful information, written by Mr Stewart, and published by A. and C. Black, Edinburgh. The book applies to *trout-fishing*, more particularly applied to clear waters; and the directions conveyed are plain, and to the point.



French Pisciculture.

FISHERIES.

WHETHER considered in reference to the natural history, the manual operations, or the economical advantages they involve, the marine fisheries of Britain form a subject of no inconsiderable interest. To the naturalist, the specific characters of the fish, their food, their migrations, and the seasons at which they become proper objects of capture, are points of attractive inquiry; while to the economist the various modes of capture and curing, the whole art, in fact, by which an unlimited natural production may be converted into a cheap and available source of human comfort, are matters of high importance. The present sheet is an attempt at a brief exposition of a branch of our commerce which is not yet well understood, either by the general public or the political economist. A complete view of the fishing interests of Great Britain naturally divides itself into two portions, the one comprising the *food*, and the other the *oil* fisheries. Deeming the food question to be of the greatest moment, we prefer devoting the greater part of our space to a review of this particular branch of our national industry—the whale and seal fisheries being of comparatively minor public interest.

I. THE FOOD-FISHERIES.

The river and sea fisheries of Great Britain are of the very greatest importance to the wellbeing of the people, whether we view them as a source from which may be drawn unlimited supplies of cheap and nutritious food, or as an outlet for the remunerative investment of a large amount of capital, and for the employment of a large body of the population. It must ever be a subject of regret to the economist that the proper development of this great source of national revenue has hitherto been much neglected. Even yet, after the lapse of centuries, we are apparently but beginning to appreciate the resources of the food-magazine which nature has placed at our command in the seas and rivers of this country. Although the development of our fisheries as a means of commerce is of comparatively modern origin, fish has been used as an article of food from the earliest ages. The rude means of capture at one time adopted, when the object was only to satisfy individual wants, have given way in the face of advancing civilisation to refined ingenuity; and the art of man has invented a machinery of nets and boats capable of capturing the finny tribe in quantities sufficiently numerous to supply in some degree the food-wants of our rapidly increasing population, and to make our fisheries no mean source of national commerce. Modern enterprise is also likely to greatly increase these supplies. Within a brief period, no less than three different companies have been started with the view of carrying on operations on a larger scale than has yet been attempted by private enterprise, and others, we hear, are projected; and for the purpose of bringing to their aid all the advantages of modern discovery, the steam-engine will be used, both as an assistant in the capture of the fish, and as a means of more speedily laying it before the public. That there will be an ample demand for the additional

fish-food that improved modes of capture may bring into the market, is quite certain. Fresh fish is rarely seen in many of our inland towns, and when a supply does make its appearance, it can be considered only as a luxury for the tables of the more opulent classes.

Some idea of the quantity of fresh fish consumed in the United Kingdom may be gathered from the following statement of what is sent to London alone. Our information is derived from an article entitled 'The London Commissariat,' which appeared in the *Quarterly Review*, No. CXC. It informs us that the railways are now, as may be expected, active agents in the conveyance of the metropolitan fish supply, and that, in addition to what arrives by means of the fishing-luggers and smacks, the Eastern Counties Railway forwards every night in the season 100 tons of herrings and other fish—or in all, 12,081 tons annually. 'The South-western Railway sends up annually, with the same speed, 4000 tons of mackerel and other fish, the gatherings of the south coast. The North-western collects overnight the "catch" from Ireland, Scotland, and the north-east coast of England, and adds to the Thames Street mart 3578 tons, principally of salmon; whilst the Great Northern delivers to the early morning-market, or sometimes later in the day, 3248 tons of like sea produce. The Great Western brings up the harvests of the Cornish and Devonshire coasts, chiefly mackerel and pilchards, to the amount of 1560 tons in the year; and the Brighton and South Coast conveys the incredible number of 15,000 bushels of oysters, besides 4000 tons of other fish.'

In Mr H. Mayhew's admirable work, *London Labour and the London Poor*, an estimate is attempted of the total quantity of fish sent to the London market, which we take the liberty of transcribing:

Description of Fish.	No. of Fish.	Weight of Fish.
Wet Fish.		lbs.
Salmon and Salmon Trout (29,000 boxes, 14 fish per box),	406,000	3,480,000
Live Cod (averaging 10 lbs. each),	400,000	4,000,000
Soles (averaging ¼ lb. each),	97,520,000	26,880,000
Whiting (averaging 6 oz. each),	17,920,000	6,720,000
Haddock (averaging 2 lbs. each),	2,470,000	5,040,000
Plaice (averaging 1 lb. each),	33,600,000	33,600,000
Mackerel (averaging 1 lb. each),	23,520,000	23,520,000
Fresh Herrings (250,000 barrels, 700 fish per barrel),	175,000,000	42,000,000
Ditto in bulk,	1,050,000,000	252,000,000
Sprats,		4,000,000
Eels from Holland (principally), England, and Ireland (6 fish per lb.),	9,797,760	1,505,280 127,680
Flounders (7200 quarterns, 36 fish per quartern),	259,200	43,200
Dabs (7500 qtns., 36 fish per qtn.),	270,000	48,750
Dry Fish.		
Barrelled Cod (15,000 barrels, 40 fish per barrel),	750,000	4,200,000
Dried Salt Cod (5 lbs. each),	1,600,000	8,000,000
Smoked Haddock (65,000 barrels, 300 fish per barrel),	19,500,000	10,920,000
Bloaters (265,000 baskets, 150 fish per basket),	147,000,000	10,600,000
Red Herrings (100,000 barrels, 500 fish per barrel),	50,000,000	14,000,000
Dried Sprats (9600 large bundles, 30 fish per bundle),	288,000	96,000
Shell Fish.		
Oysters,	495,896,000	
Lobsters (averaging 1 lb. each fish),	1,200,000	1,200,000
Crabs (averaging 1 lb. each fish),	600,000	600,000
Shrimps (324 to a pint),	498,428,648	
Whelks (227 to half-bushel),	4,943,200	
Muscles (1000 to half-bushel),	50,400,000	
Cockles (2000 to half-bushel),	67,392,000	
Periwinkles (4000 to half-bushel),	304,000,000	

Fish, as an article of diet, yields much nutriment, and is greatly esteemed by all classes; of all substances used as food by mankind, it is perhaps the most liable to get into a state of putrefaction, and should therefore be eaten when fresh. Those fish that are whitest and most flaky when boiled, as turbot, soles, cod, haddock, whiting, and flounders, are most easy of digestion; those which abound in oily matters, as salmon, herrings, and eels, are more nutritious, but not generally so digestible. As to the relative nutritive properties of fish and other animal food, Professor Brande states that 'when the muscular parts of animals are washed repeatedly in cold water, the fibrinous matter which remains consists chiefly of albumen; and is, in its chemical properties, analogous to the clot of blood.' Muscle yields also a portion of gelatine; and the flesh of beef and of some other animals affords a peculiar substance, of an aromatic flavour, called by Thenaud *osmazone*. Albumen and gelatine, then, constitute the leading nutritive ingredients in the different kinds of flesh used as food, and it is important to observe that their relative proportions are not very dissimilar in quadrupeds, birds, and fishes, as shewn in the following table. The water was determined by evaporation in a close-covered vessel, or at a temperature below 212°:

100 Parts of Muscle of	Water.	Albumen or Fibrin.	Gelatine.	Total of Nutritive Matter.
Mutton,	71	22	7	29
Chicken,	73	20	7	27
Beef,	74	20	6	26
Veal,	75	19	6	25
Pork,	76	19	5	24
Cod,	79	14	7	21
Sole,	79	15	6	21
Haddock,	82	13	5	18

According to Johnston, fish in general is less rich in fat than flesh meat.

Fish, when *out of season*, are unwholesome and not good: they are said to be sick; but, by a wise provision, the time varies with the different kinds of edible fish, so that some may be had good at all times throughout the year. The following table is applicable to the British markets, and enables us to see at a glance what fish are in season and what kind are out of season, during every month of the year; and also which kinds are in their best state for present use:

FISH TABLE.

S denotes that the Fish is in Season; F in Finest Season; and O out of Season.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Brill,	S	S	S	S	S	O	O	O	O	S	S	S
Carp,	S	S	S	S	S	S	S	S	S	S	S	S
Cockles,	S	S	S	S	O	O	O	O	S	S	S	S
Cod,	F	S	S	O	O	O	O	O	S	S	S	F
Crabs,	O	O	O	S	F	F	F	F	F	O	O	O
Dabs,	S	S	S	S	S	S	S	S	O	O	O	O
Dace,	F	F	O	O	O	S	S	S	F	F	F	S
Eels,	S	S	S	O	O	O	O	S	F	F	F	S
Flounders,	S	S	S	O	O	O	O	O	O	S	S	S
Gurnets,	O	O	O	O	S	S	S	S	S	O	O	O
Haddocks,	F	S	O	O	S	S	S	S	S	F	F	F
Halibut,	S	F	F	S	S	F	F	S	S	S	S	S
Herrings,	S	O	O	O	S	S	F	F	S	S	S	S
Ling,	S	S	S	O	O	O	O	O	S	S	S	S
Lobsters,	O	O	O	S	F	F	F	S	S	O	O	O
Mackerel,	O	O	O	S	S	S	S	O	O	O	O	O
Mullet,	O	O	O	S	S	S	S	O	O	O	O	O
Muscles,*	S	S	S	S	O	O	O	O	S	S	S	S
Oysters,	S	S	F	F	O	O	O	O	S	S	S	S
Plaice,	S	O	O	O	S	S	S	S	S	S	S	O
Prawns,	O	O	S	F	F	F	F	S	O	O	O	O
Salmon,	O	S	S	F	F	F	S	S	O	O	O	S
Shrimps,	S	S	S	S	S	O	O	O	S	S	S	S
Skate,	F	F	F	F	F	F	S	S	O	O	S	S
Smelts,	S	S	S	S	S	O	O	O	O	O	S	S
Soles,	S	S	S	S	S	S	S	S	S	S	S	S
Sprats,	S	O	O	O	O	O	O	O	O	O	O	O
Thornback,	O	O	O	O	O	O	S	S	S	S	S	O
Trout,	O	S	F	F	F	F	S	S	S	O	O	S
Turbot,	S	S	S	S	S	S	S	S	S	S	S	S
Whitings,	F	F	O	O	O	S	S	S	S	S	S	S

* In the Firth of Forth, muscles are collected all the year round, but they invariably fall off in condition during the prevalence of easterly winds.

THE SALMON-FISHERIES.

Although not the representative of so large an amount of capital as some other fish, the salmon is of great value, and is considered one of the luxuries of the table. During late years, the decline in the British salmon-fisheries has become so notorious, as to be now attracting very great attention. At one time, this fish was exceedingly plentiful; so much was this the case, that in many of the towns of Ireland and Scotland, it was retailed at the cheap rate of 2d. per pound. Of course, it is many years since these prices were current; the opening up of the distant markets of London, and even those in the cities of the continent, consequent upon the introduction of steam-transport, soon placed salmon on a par, as to price, with venison and other game. The opening up of so many new markets has induced more active fishing; and no doubt this has been one of the causes of the declining supply of our rivers of late years. The rental of our best waters has fallen, in some instances, to one-third of what it was in former years, when this fish was captured in hundreds instead of in tens, as at present. As to over-fishing, the salmon proprietors are beginning to find out their error; at a meeting of the Tweed commissioners, held in October 1856, Lord Polwarth called to mind his having said, thirty years ago, that 'they were living upon principal and interest, a system which would ruin any property.'

The modes of taking salmon are various; differing according to the nature of the locality, be it sea-shore, tidal estuary, or running river. Along the shores of the open sea and estuaries, the salmon is continually traversing and retraversing during summer, and in such situations the stake-net is generally employed. This consists of a long wide-meshed net, supported on poles, which runs seaward in a straight line between high and low water-mark. From this main line various bending offsets are made, so as to form chambers or traps. As the fish push along shore, they are intercepted by the main line of net, and find their way into one or other of the traps, from which there is no retreat. Higher up the rivers, sweep-nets are used, one end being made fast to the shore, and the other run rapidly out by a boat, so as to enclose any fish that may be seen ascending. As soon as a salmon is observed by the outlook, a signal is made, the net run out as described, and then dragged on shore, encircling the object of capture. The central portions of wide rivers are usually worked by fishermen in boats called *cobles*, with long sweeping seine-like nets—a laborious, but not unsuccessful process. Still higher up, in certain rivers, weirs or dams are built, with enclosed places in the dam-wall called *cruives*. The fish as they push up the stream, enter these spaces, through which the water rushes, and are prevented by a grating of peculiar contrivance from getting out. In some places, stages are erected, from which fishers with bag-nets intercept the ascending salmon; and at linns or waterfalls, spearing is occasionally resorted to. By one or other of these methods immense numbers of salmon are annually taken.

The salmon is a victim to the depredations of pirates of all kinds, more than any other fish, and this is suggested as being another of the causes of its increasing scarcity. The spawn is exposed to the greatest injuries which the floods in the breeding-rivers can inflict; whole beds of it being carried away by the 'spates' of winter, long before the egg has time to be hatched. And if fortunate enough not to be swept away by the flood, the eggs or ova become the prey of trout, worms, the larvæ of insects, and water-fowl, or are parched by the sun, if the water which covers them should happen, as is often enough the case, to be dried up, or run into a new channel. Even when spared from all these perils, the instant it is hatched the fish is exposed to new dangers; and more especially in the state of the parr is it destroyed in thousands, becoming the easy prey of every juvenile angler in the neighbourhood of our salmon-rivers. Instances, indeed, are known where these valuable fry have been caught in incredible numbers, for the purpose of feeding the swine of the neighbouring cottagers.

There are also many other causes which may have influenced the declining supply; prominent among these we would rank the enormous destruction of grilses, and the annual massacre of the spawning fish. When we find, as is frequently the case, that the capture of grilse at some of the fishing-stations far outnumbers that of salmon, and when it is considered that not one of these fish has been allowed to deposit its spawn before being killed, it will be at once seen how much this will in time affect our supplies. Each of these grilses, which the greed of profit induces people to kill before they are allowed to breed, will average from four to five pounds' weight, and as the spawn is supposed to average 1000 eggs for each pound the salmon weighs, the number of future fish which are thus destroyed must be immense. For instance, during the last five years, the take of grilse on the Tweed has been, in round numbers, 140,000; in former years, it has averaged much higher than that; but if we assume the spawn in each of the female fish at 3000, and take two-thirds of the number as females, or take 100,000 as such, the quantity of eggs thus destroyed would be nearly 300,000,000. If we suppose even a hundredth part of this number of eggs allowed to grow up and reach the fishmonger's shop in the shape of full-grown salmon, we may see how completely the salmon-proprietors have been exemplifying the proverb, and killing the goose that laid the golden eggs. Another evil with which salmon have to contend, is the system of netting and leistering which prevails, and which is most resorted to in the breeding-time. The rivers are now so well watched as to have rendered the practice more infrequent than it was in the days of Sir Walter Scott and the Ettrick Shepherd, both of whom have described it with great power. Still, there must be a considerable loss from this source of illegal capture, as we have the means of knowing that salmon-poaching and the sale of foul fish are still carried on to a large extent. At the meeting already alluded to, the Duke of Buccleuch stated, that in the upper part of the Tweed—and we take it as an example—there was an enormous and wholesale destruction of fish. It was only by his own exertions and personal influence, he said, that immense destruction was prevented in the Ettrick and Yarrow, where the peasantry thought they had a 'right' to kill the fish when they could get them.

'The whole matter,' says a recent writer in the *Quarterly Review*, 'has been one of dispute for more than two centuries; but all are now agreed, that a timely cessation from wholesale slaughter is indispensable. The owner of fixed nets at the river's mouth keenly urges the propriety of allowing it to commence in the earliest part of the year, when salmon first approach the estuaries—are in the primest condition—and when, as they are scarce, the price in the market is high. As his "engines" have, owing to their position, the priority of capture, an early commencement would enable him to secure a large proportion of the best fish. On the other hand, the public fishermen of the tideway, the more inland landowners, the lessee of the solid weir, and those gleaners, the anglers, all oppose an early commencement, as depriving them of their chance for the bounty which nature directs towards them at a later period. They desire that the open season should not commence until the fish begin their ascent. But they often fall into the extreme of wishing to continue to fish too late: at that period when salmon is plentiful enough, but when its presence in the fresh water proves that it is hardly fit for food. Whatever may be the fence-months, the lower proprietor must enjoy the advantage of his position: but the law, as it stands at present, has given him a degree of monopoly,

in permitting his nets to commence operations at the earliest time at which salmon enter the rivers, and to continue as late as any higher up (except the anglers) may fish.'

Remedies are now anxiously sought for this state of things; and attempts are making to stock our rivers afresh by artificial means. Considerable results have already been achieved, by the experiments in 'pisciculture' (see ANGLING) at Stormontfield, on the river Tay, near Perth; and there can be no doubt that, if these be persevered in for a sufficient length of time, the supply of this fine fish will be sensibly increased; as the ova, when deposited in the usual way, are exposed to great danger, as we have already described; and every process which is calculated to shield either the eggs or the young fish from danger, must evidently be an aid in the multiplication of the species.

The greater part of the salmon taken in the rivers of Scotland and Ireland is at once despatched to London and the other large towns of the kingdom; part is also exported to the continental cities. It is usually kept fresh by being packed in ice; formerly, salmon was mostly disposed of 'cured,' and in its dried and pickled state a large trade was carried on with various Catholic countries, where it was much in demand during Lent. In Scotland, and also in England and Ireland, about the end of last century, this fish could be purchased in a wholesome condition at the low price of one penny and twopence per pound-weight. Then, in every farmhouse near the salmon-rivers, 'the venison of the waters' was a constant dish; and every peasant had his barrel of pickled, or his row of smoked salmon. Now, there is no such thing. No article of food is so rare; and a large fish is more valuable in London than a good fat sheep. In England, there are no fisheries for salmon that are worth naming. Most of the rivers have been long exhausted; and a Thames salmon, it is said, would be almost priceless. There are splendid salmon-rivers in Ireland, and some of the streams in that country still yield a very large supply of fish for the Liverpool and London markets, as well as for home consumption. It is difficult to ascertain accurately the produce of the Irish salmon-rivers in recent years, but that previous to 1842 the 'take' of fish was considerable. A writer on the subject says the average annual take of salmon at that period may be reckoned at 200 tons for each of the chief fisheries. 'The Foyle fishery in 1842 produced nearly 300 tons; and it is a remarkable fact that, in the reign of Charles I., the produce of the Foyle is stated at 240 tons for the year 1638; the Bann at Coleraine previously, also, had been equally fruitful; and the Shannon superior to all. Shortly anterior to 1842, in one town on the Shannon—the town of Glin—£8000 worth of salmon was sold in one season. The great fishery of the Moy, at Ballina; the Blackwater, at Lismore; and last, though not least, the Erne, at Ballyshannon, produced also their hundreds of tons.' The writer to whom we are indebted for these statistics —Mr Worthington—tells us in a part of his volume that these fisheries are now in a state of comparative decay, doubtless from the same cause which has affected our Scottish rivers — injudicious and over fishing, poaching, &c.

Very large rentals were at one time derived from the Scottish salmon-fisheries; in fact, the rent of some fishing-stations, and these perhaps small in extent, greatly exceeded that of a farm of hundreds of acres. And be it recollected this valuable property cost the landlord very little expenditure in return; there was no expense incurred for farm-buildings, for draining, for fences, and other sources of outlay incurred by land. The value of those fisheries has greatly declined of late years; if we take the Tweed as an index to other rivers, we find that its fishings, which were rented in 1814 for £20,000, now produce only a fourth part of that sum; and the number of boxes of salmon at present despatched from Berwick-on-Tweed is only 3000, whereas five times that quantity has been known to be sent. But, notwithstanding all this falling off, the supply of salmon sent to London alone is still very considerable. Mr Saunders, a practical authority on such subjects, estimates it at above £100,000 per season for fresh fish only.

If we except the far-famed Lochleven trout, there is not in Great Britain any commerce worth mentioning in fresh-water fish, besides the salmon and the salmon-trout.

Artificial Fish-breeding.

Were the French system of repeopling the waters by means of pisciculture, adopted in our numerous lochs and streams, a very large extension of the fish-trade might be looked for, and a considerable addition made to the existing varieties in the fish-market. The frontispiece gives a view of the fish-hatching apparatus exhibited at the Paris Agricultural Show, which represented the experiments carried out by the French government for restocking their principal rivers and lakes. Many of the rivers of France and Germany have been rendered valuable by means of this system of artificial hatching and nursing, introduced by Gehin and Remy, and there are no obstacles to a similar development of the river-fisheries in Great Britain. By this means, in addition to multiplying our present stock of fishes, new species might be introduced—as the ova can be packed and sent to any distance with great facility.

We are glad to observe that arrangements are in progress in various parts of Great Britain, for the further development of our fresh-water fisheries. A Salmon Fishing Company, on the limited liability principle, has commenced operations on the beautiful river Dart, in Devonshire. It has been planned, we understand, by Mr Gottlieb Boccius, and the system of artificial rearing will be here carried on to a large extent. If successful, we have no doubt of its giving rise to numerous other enterprises of a similar kind. The rivers, canals, and lochs of Scotland are particularly favourable to an extensive cultivation of fresh-water fishes. A writer on 'Salmon' in the *Agricultural Journal* for March 1857, throws out the following suggestions on this part of the fishery question: 'In Scotland, we have about 180 miles of canals. Why are they fishless, when they might be easily stocked with many valuable species of fish? Why do the Water Company (of Edinburgh), owners of the Compensation Pond among the Pentland Hills, not encourage the breed of so valuable a fish as the sea-trout? Why not try to swell their annual dividend by the introduction into their capacious reservoirs of the species of salmon so abundant in Lake Wenern!' The writer also suggests the Loch of Lindores, 'within half an hour's journey from the populous towns of Perth and Dundee, and distant from Edinburgh and Glasgow not more than two and four hours respectively,' as a fitting locality for experiments in pisciculture; and he further recommends the introduction into Britain of the delicious Canadian fish called the black bass. 'This is one of the finest of the American fresh-water fishes. It is surpassed by none in boldness of biting, in firm and violent resistance when hooked, and by a very few only in excellence upon the board. It bites ravenously at a small fish or minnow tackle, and also affords excellent sport with an artificial fly. It attains the weight of six or eight pounds.' The success of the experiments performed at Stormontfield, in a commercial view, are quite conclusive, as the following memoranda, gathered from the books of the superintendent, will at once demonstrate:

1. Of the marked fish which were liberated from the pond at Stormontfield, four out of every hundred were recaptured, either as grilse or salmon.

2. We find that more than 300,000 fish were reared

in the pond, and allowed to go into the Tay. Thus, 40 fish out of every 1000 were recaptured; and as 300,000 were in all liberated, it follows that 12,000 of the salmon taken in the Tay were pond-bred fish. But, as the fish did not all go away in one year, this 12,000 must be distributed over two years.

3. We find the average number of salmon and grilse taken in each year is 70,000. It follows, then, if there be any truth in figures, that nearly one-tenth of the fish taken in the Tay for the last two years were artificially bred. This is equivalent to a rise of 10 per cent. in the rental of the fishings; and such, we find, is the result.

THE HERRING-FISHERY.

There is perhaps as much mystery attending the natural history and habits of the herring at the present time, as there was about those of the salmon forty years ago. It is ranked by naturalists in the same family with the pilchard, sprat, shad, anchovy, and white-bait. The body, which is about ten or twelve inches in length, and of a handsome, regular shape, is covered with thin roundish scales; the upper part is blue or green, according to the light, and the lower of a silvery white. The belly is carinated, but not serrated, as in the sprat—a distinction which is obvious and permanent. Owing to the gill-covers being very loose, and opening wide, the animal dies almost the instant it is taken out of the water. Even in the nineteenth century, we have not entirely got over the ancient and once popular myth of this fish being a native of the great arctic seas, and instinctively rushing, at the proper season, in vast shoals to these islands, in order to be captured and become the food of man. Naturalists, however, now know as much of the habits of this fish as to be able to refute the old theory, and to state with certainty that it spawns upon our own coasts; but where it proceeds to after accomplishing this process, is somewhat doubtful. Some naturalists aver that the herring never leaves our own seas, but that, after the season of spawning is over, it merely retires from the shores into deep water. This again is denied, as, were it really the case, the cod and ling found in the deep sea would certainly prey upon it; but this, it is ascertained, is so rarely the case, as to lead to the conclusion that the herring do not rendezvous even in the deeper parts of our own seas. A writer on this subject says: 'The larger herrings, of which the great western shoal is composed, seemed to wander, while in the state of fry, to the Northern Ocean, whence they return periodically, on coming to maturity. This is inferred, because it is certain the further north, the earlier this fishing commences; and because the shoal, when it first comes, is always attended by arctic gulls, whose plumage differs from that of the common herring-gull on the coast of Scotland.'

The herring-fishery, when pursued on a large scale, is carried on by means of what are called *drift-nets*, the meshes of which are regulated to an inch in size by act of parliament. A single net is generally about fifty feet long, and from thirty to thirty-five feet in depth, and the cost of it is from £4 to £5. For the purpose of capturing the fish, the various nets are joined together into what is termed a *train*, which may run to any length, but is generally from 500 to 2000 yards—long trains being preferred to short ones. The whole is held in position by the *back-rope*, a strong cord running along the back of the train, and which has fixed to it the buoys, which keep the netting afloat. The train is held down in the water by means of weights. The boats necessary for carrying such a load of netting, it is obvious, must be of considerable value; the best class of them costing upwards of £100.

The boats arrive at the proposed fishing-place in the evening; the nets are shot after sunset, as the fish always strike best in the dark; and the catch takes place throughout the night. The process of throwing a train of nets into the sea is quite simple: it is *paid* over the stern of the boat, which is slowly rowed over the part of the sea selected as being most likely to be in close proximity to the shoal. When all the nets forming a train have been shot, a rope about twenty fathoms long, which is technically called the *swing-rope*, keeps the last one attached to the boat. Sometimes the other end of the train of nets is fastened to an anchor, or it may be to the shore, when that plan is convenient; but more generally the whole length is only fastened by the swing-rope to the boat, and is allowed to float slowly along, carried away by the tide or current—a great perforated wall, 2000 feet long, and 24 feet deep, standing upright in the water. When the shoal, in its progress, comes against this barrier, the fish are caught by what is called *meshing*—that is, by thrusting their heads through the interstices of the net, and being entangled by their gills. Sometimes the fish have to be waited for long, and perhaps, after all, none may be got that night; while at other times a heavy take may occur in less than an hour. To ascertain whether or not the fish may have struck the net, a custom exists of *preeing* the nets—that is, lifting out a portion of a train and examining it. If there be no appearance of fish, the labour of hauling in the nets, removing to a new spot, and again shooting, has to be undergone, in the hope of being at last lucky enough to hit upon a better spot. Supposing the fish to have come upon the train of nets, the process of hauling into the boats and taking the herring out of the meshes, is commenced. Formerly, it used to be the practice just to haul in the net, and leave the fish sticking in it by the gills till the boat landed; now, as the nets are hauled on board, the herrings are carefully shaken out, a decided improvement on the old plan, which frequently mutilated the fish to a very serious extent.

The town of Wick in Scotland, may be said to owe its existence to the herring-fishery; in fact, the popular saying of being founded on herring-bones is as applicable to the thriving town of Wick, as Amsterdam. It possesses a large population, all engaged more or less in the fisheries; and the capital represented by boats, nets, &c., amounts to nearly £60,000. The greater part of the fish taken at Wick are cured for exportation—a trade requiring a large amount of tonnage, and upwards of 1000 men to carry it on. The gutting and packing also, give employment to a great variety of persons, chiefly women, as well as to a number of boats which convey salt from Liverpool, as well as from foreign ports. The whole process of curing may be seen in Wick to the greatest advantage; and it has been thus described:

'When the herrings are captured, and the boats reach the harbour, the process of curing them begins. Immediately on their arrival, the fish are carried to huge but shallow gutting-tubs prepared for their reception. Once there, they are operated upon by a band of females, who gut them with a rapidity which is quite extraordinary. One thousand fish in an hour being the common work, it may be readily conceived that, when a large number of hands are employed, an immense shoal can be disposed of in a few hours. The women employed, usually work together in a little band of four or five, each performing a part of the labour which is necessary, some carrying, some salting. After the fish are eviscerated, which is rapidly performed by two simple movements with a knife, they are transferred to another vat or trough, where they are laid down in layers of alternate salt and fish. The sooner the herrings are sprinkled with salt, the better for the *cure*. Then they are *roused*, as it is called—that is, a stick or a brawny arm mixes them well together—a process repeated at intervals till the trough is filled. After a brief rest, depending much on circumstances as to its length, the herrings are carefully resalted, and then packed into barrels, either flat on their sides—to suit the Irish market—or backs

downward, to please the foreigners. Every row, as it is put in, is well sprinkled with salt. A week's rest is allowed before the barrels are finally headed up, as the fish settle down so much as to admit of an additional quantity being put in. When intended to receive the brand of the Fishery Board, the barrel must remain open for ten days.'

The annual reports of the Commissioners of British Fisheries give ample statistics of the herring-fishery. From the tables compiled in these documents, we perceive that, amid considerable fluctuations, there has been a gradual increase for the last fifty years in the quantity of fish cured, and the quantity exported. Of course, there is no account of what has been consumed in a fresh state, as that has not been taken cognizance of by the officers of the Fishery Board. The year in which the reports commence is 1809, when the total quantity cured was little more than 90,000 barrels; in 1810, the amount is nearly the same; but after that period it rapidly increases, till the quantity is measured by hundreds of thousands of barrels. The three highest years are as follows: 1850, 770,698 barrels; 1853, 778,089 barrels; 1855, 766,988 barrels. The total quantity of herrings cured during 1856 was 609,988½ barrels; the total quantity branded, 223,281; and the total quantity exported, 347,611¼—being a decrease upon the preceding year of 156,715 barrels in the quantity cured, of 57,300¼ in the quantity branded, and of 94,652¾ in the quantity exported. From the account of the herrings caught, but not cured, it appears that the quantity in 1856 amounted to 107,685 barrels or crans—being a decrease upon the preceding year of 23,074 barrels or crans; and when this account is added to the amount of herrings cured, the total produce of the herring-fisheries for 1856 amounts to 717,673½ barrels—being a decrease upon the preceding year of 179,789 barrels or crans.

The herring-fishery has, from a very early period, been a source of wealth to this country, particularly to Scotland. Evidence of the fact is to be found in the ancient acts of parliament, and in various other historical documents. 'It appears from a manuscript of Sir Robert Sibbald, that, before the Union, 600 boats, with above 4000 men, have been seen at once employed in the herring-fishery in the Firth of Clyde alone, which afforded in a year 3750 tons of herrings for exportation; that a small tract upon the coast of Fife, not above twelve miles in length, fitted out 168 boats, manned with 1120 fishers, and usually exported about 12,000 barrels of herrings; and that in the year 1695, the small town of Crail in Fife, exported above 2400 barrels. What quantity was exported from the whole of the Forth, from the Murray Firth, where the fishery was still more considerable, and from other parts of the kingdom, does not precisely appear; but from general report, it seems to have been great, compared to what it has been ever since. . . . After the Union, the enactment of the salt-duties, and the complicated regulations established for their management; the difficulties in obtaining salt, and the great risk incurred by traders entering into salt bonds, at once depressed the fisheries of Scotland, which for some time had worn the most promising appearance.'

The amount of capital at present invested, and the number of people employed in the Scottish herring-fishery, are very considerable. The boats, netting-lines, and other equipments—are valued (1854) at upwards of half a million sterling. The amount is thus divided: boats, £225,830; nets, £303,666; lines, £57,924. The boats engaged in the Scotch fisheries, including a few hundreds from the Isle of Man, make a fleet of 11,000; and the number of persons engaged in the trade cannot be less than 70,000. The number of fishing-luggers belonging to Great Yarmouth is said to be about 300, carrying ten men each. These vessels are chiefly employed in the mackerel and herring fisheries during their seasons. There are also a number of trawl-fishing smacks belonging to the port, and upwards of fifty boats employed in the shrimp-trade. M'Culloch estimates the capital invested at Yarmouth and Lowestoft at a quarter of a million sterling. This latter place employs about seventy boats, of forty tons each. The greater number of the herrings taken at Yarmouth and other places are cured in Manchester, and known in London and throughout England by the name of Yarmouth bloaters. It may likewise be mentioned that Hastings and Folkestone on the English coast have capital herring-fisheries, and that a large portion of the fresh fish which reaches the metropolis is sent from these towns; they are also caught in Cardigan and Swansea Bays. The Irish herring-fisheries are not worked as they ought to be; hence Ireland, although its coasts abound with fine fish, derives the chief portion of its herring supply from the north of Scotland.

THE PILCHARD-FISHERY.

The pilchard is not unlike the herring, and was at one time caught in the principal Scottish estuaries. Up to the year 1816, it used to be taken in great quantities in the Firth of Forth. At the present time, the principal resort of this fish is the coast of Cornwall, where its capture gives employment to a large number of people, and a considerable amount of capital is required to carry it on. The following account of this fishery is abridged from a graphic letter which appeared in the columns of a provincial newspaper:

'This fish is nowhere seen but on the coast of Cornwall, and is only to be found for a brief period of two or three months. They arrive to the eastward of the Land's End about the end of July, and they continue to the beginning of October. They are afterwards seen on the north coast of the county, where the fishing is carried on for a few weeks later. They then disappear, and whither they go is as yet unknown to naturalists, but they are supposed to come from the Atlantic. The size of the shoals and the closeness to which they approach the shore vary much in different years, making the fishery rather a speculative undertaking. Notwithstanding a comparatively good year now and then, this branch of our fisheries is not so important a source of wealth to Cornwall as it was forty or fifty years ago.

'An account of the manner in which the fish are caught and cured may be interesting to those who do not already know it. They are fished for in two ways: by *seines*, in which far the greater number are taken; and by *driving*. The latter is similar to the mode followed for the capture of herrings. The pilchard *driver*, or boat, is deep, square-sterned, and generally yawl-rigged. Like the herring-boats, they can stand heavy weather, and sail remarkably fast. But the seine-fishing is something novel; and the fish taken in this manner bring the highest price in the foreign markets. A seine, with the necessary boats, grapnels, and gear, costs about £1500. From the amount of outlay which is required, they are generally the property of capitalists, but are sometimes held by a company, and divided into small shares. Twenty men are employed on each seine, who are paid by small wages—generally eight shillings a week—and a share in the profits. The seine measures in length 220, and in depth from 16 to 18 fathoms. On one edge are placed corks, and at the other leaden weights; and this enormous net is carried in a large boat or lighter, and thrown overboard so as to encircle a shoal of fish when they can be found in water not deeper than the seine. As soon as the fish are surrounded by this hempen wall, anchors are carried away from different parts of the seine, and it is safely moored; and unless stormy weather comes on, the fish may be kept there, and taken out at leisure. At Mevagissey, on one occasion, when salt became scarce, the seines were left in the water, and the fish kept alive till a vessel went to Normandy and brought back a cargo of salt. The fish are lifted out of the enclosed space with a smaller net called the *tuck-seine*.

This is done at low-water and at night, as the fish during the day remain near the bottom, and any attempt at raising them would result in the tearing of the net. *Tucking*, or lifting out the fish, is thus accomplished: The boats in which the fish are to be carried are brought close to the seine, and the small net is drawn tight; two men sit on the gunwale, and with a two-handled basket lift the fish and pour them into the boat. The strange silvery light caused by the living mass of fish, the joy of the fishermen, which breaks out every now and then into songs and shouts, which are echoed from the bold cliffs in the vicinity, make this part of the operation beautiful and interesting. A shoal of fish changes the colour of the water; and this is observed most easily an hour before sunset, at which time the seiners are all silent, and intently watching the water. Much depends upon the eye and judgment of the master-seiner, who accompanies the larger boats in a small boat called the *lurcher*. If the seine should enclose 200 hogsheads, it is considered a successful shot; but as many as 1500 hogsheads have been surrounded by a seine at one time. It, however, often happens that the fish are travelling so rapidly through the water, that they escape whilst the men are casting the seine overboard.'

The average number of hogsheads exported is about 25,000 per annum; and the wholesale price may be stated at £2, 10s. per hogshead. Each hogshead contains about 3000 fish. The fishery varies very greatly. Instances have been known of quantities sufficient to fill 10,000 hogsheads being taken ashore in one day.

The following is the mode of dealing with the fish after they are captured. When they are intended for exportation, they are carried into cellars and *bulked*—that is, laid in rows in a heap, with a layer of salt between each layer of fish. After lying in the salt for a month, they are washed and packed into casks; but before the casks are *headed*, the fish are pressed down; the casks are then filled up, and again pressed; and after being a third time submitted to pressure, the casks are closed up, and considered ready for shipment. The fish being so pressed, keep much better in the warm climate to which they are sent, and a large quantity of valuable oil is produced. It is calculated that fifteen hogsheads of pilchards produce a hogshead of oil; so that the produce of this oil adds considerably to the value of the pilchard-fishery, as it sells for £42 per ton; and the scum, or garbage, as it is called, which rises to the surface in the washing-troughs, is purchased by the soap-manufacturers at about £10 a ton. The quantity of salt required is very considerable—eight bushels to every hogshead of fish—but the undissolved salt, which is more than half the quantity used, is sold readily for manure at 20s. a ton. A good year's fishing returns large profit to the curers, and supplies cheap food and remunerative employment to those engaged in its capture.

THE SPRAT-HARVEST.

The sprat, or, as it is called in Scotland, the garvie, is an important member of the *clupeidæ*, and is by some authorities described as the young of the herring—an opinion which is, however, scouted by others. After the errors which prevailed so long concerning the natural history of the salmon, we ought to be careful how we pronounce judgment on this subject; and as there is so much ignorance as to the herring itself, it is just possible that the sprat may be a young herring. The writer in the *Quarterly Review*, No. CXC., says, in speaking of this fish: 'Next to the herring-fishery, the sea-harvest of most importance to the poor of London is that of sprats, which come in about Lord Mayor's day; and it is a popular belief that the first dish is always sent to the chief-magistrate of the city. If a telegraph were to be laid down to all the alleys and courts, the fact of a large arrival of these little creatures at Billingsgate would not be sooner made known to the lower orders than by some mysterious process it is at present.'

As will be seen from our table, the sprat is in season for about three months—the fishing commencing in November; the greatest quantities are caught on very dark or foggy nights. Many thousand tons are sometimes taken; and, in lack of a better market, have to be sold at a few pence, to the farmers, as manure.

The far-famed white-bait is also a member of the herring family. It is a very small fish, of silvery lustre, and is found in the brackish waters of the Thames during the months of summer. It is also found in the river Hamble, which flows into Southampton Water, and, according to Parnell, it can be taken between Queensferry and Kincardine on the Firth of Forth in great quantities. White-bait dinners are in great repute amongst the aristocracy of London, who resort to Greenwich or Blackwall, to enjoy the fish in its finest condition. Pennant says of this fish: 'They are esteemed very delicious when fried with fine flour. They come into season about March or April.'

THE WHITE-FISHERY.

Under this term is included not only the fishery of the common cod, but that of the haddock, whiting, ling, hake, torsk, and others—all remarkable for the excellence of their flesh, which is white, firm, separates readily into flakes, is agreeable to the taste, and wholesome. They belong to the soft-finned fishes, and constitute a family of great extent and usefulness, known by the name of *Gadidæ*, and found in every sea but the Mediterranean. They live for the most part in the seas of cold or temperate climates; and from their size, and their tendency to congregate in particular localities, as well as from the value of their flesh, they are of great importance to man. As our space will not permit us to notice individually the members of this extensive family, we shall direct attention chiefly to the cod, as the head and representative—premising that the natural habits, modes of capture, curing, and preparation, are much the same in all.

The great seat of the cod-fishery is at Newfoundland and other places on the coasts of North America, and the trade there is mostly in the hands of the French and Americans. Vast quantities of this particular fish are caught, and are constantly imported into this country in a dried or cured state, constituting a well-known article of commerce. In Great Britain, the chief seat of the cod and ling fishery is in the north of Scotland, although great supplies are also found on the coast of Ireland, and on some parts of the English coast. The cod-fish is very voracious; a favourable circumstance for the fishermen, who experience little difficulty in taking them with almost any bait, whenever a favourable locality is ascertained. As these fish generally inhabit deep water—from twenty-five to forty, and even fifty fathoms—and feed near the ground, on various small fish, worms, crustacea, and testacea, their capture is only attempted with lines and hooks. The most common mode is by deep-sea lines, called *bulters*, on the Cornish coast: these are long lines, with hooks fastened at regular distances along their whole length, by shorter and smaller cords called *snoods*. The snoods are six feet long each, and placed on the long line twelve feet from each other, to prevent the hooks from becoming entangled. The line has an anchor or grapple and a buoy at each end, and is laid, or *shot*, across the direction of the tide; after being left for about six hours, it is hauled up for examination.

The fishermen, when not engaged in shooting, hauling, or rebaiting the lines, fish with hand-lines, armed with two hooks kept apart by a strong piece of wire. Each fisherman manages two lines, holding one line in each hand; a heavy weight is attached to the lower end of the line not far from the hooks, to keep the bait down near the ground, where the fish principally feed.

Vessels now sail as far as Davis' Strait and to the Faröe Islands for fresh cod, and quantities are carried alive in welled smacks all the way to London. Boats of this kind, for preserving alive the fish taken at sea, came into use in this country early in the last century. They are said to have been first built at Harwich, in 1712, by an ancestor of Mr Saunders, the fish-factor of Billingsgate; and it is remarkable that some of them were engaged in conveying troops at the time of the rebellion of 1715. The store-boats remain as far down the Thames as Gravesend, because the water there is sufficiently mixed to keep the fish alive. If they were to come higher up, the fresh water would kill them.

The greater part of the cod which are caught on our shores are brought to market as cured fish, and the process of curing is as follows: The fish are usually killed and cleaned as soon as taken. When brought on shore, they are opened up from head to tail, and a portion of the backbone is cut out. They are then carefully washed and purified from blood by copious libations of clean salt-water. After being drained, which is the next process, they are laid down in a long vat, in alternate rows of fish and salt, heavy weights being placed upon the layers, to keep them under the action of the pickle. After a time, they are taken out of the vat, again washed and brushed, and gathered into little heaps to drain. This being effected, they are spread out individually to *pine* by exposure to the sun and air. Next, they are built into heaps called *steeples*, to await the appearance of what is technically called the *bloom*, a whitish substance which comes out on the fish. This completes the business. In Yorkshire, the curers improve on this plan, by placing the fish on wooden erections made of cross-bars, which admits of their drying much sooner, keeps them cleaner, and obviates numerous accidents which occur to those dried on the ground.

Upon the cod and ling fisheries of Scotland, the commissioners, in their report for fishing (1855), say: 'The Board have to report that they shew an increase of nearly 10,000 hundredweights upon those of 1854, which, again, were an increase upon the preceding year. The exportation to Spain, in 1854, was 5630 hundredweights; in 1855, it was 14,520 hundredweights. Although the cod-fisheries can never be expected to be so productive, or to give employment to so many hands, as the herring-fisheries, they are valuable, and capable of considerable extension, especially if the import-duties in several of the fish-consuming countries of Europe were not so high as almost to debar the importation of British cured fish. The evils of a moist climate, which is most unfavourable to the cure of cod and ling, will always have to be contended against in this country; but a great deal more fish of a high character could be prepared if there were markets for them. Voyages to a considerable distance would be undertaken; and as a large fleet of French vessels proceeds to Iceland and the Faröe Isles, stimulated by the gain made in this fishing, from exclusive command of the French market, so, under more liberal commercial arrangements, the fishing crews of British boats might be encouraged to the like enterprise, and become, as the French do, skilful navigators from such long sea-voyages.'

The following statistics for the Scottish cod and ling fisheries of 1856, are from an official source: The returns shew that 110,504¾ hundredweights were cured dried, and 6642 barrels cured in pickle, and that the total quantity exported was 29,629¾ hundredweights—being a decrease in 1856, as compared with 1855, of 3056¼ hundredweights in the quantity cured dried, but an increase of 325½ barrels in the quantity cured in pickle, and also an increase of 475¼ hundredweights in the total quantity exported. The quantity of cod and ling caught, but not cured, amounts to 59,987 hundredweights, being a decrease upon the preceding year of 3552 hundredweights; and when added to the quantity cured, makes the produce of the cod and ling fisheries for 1856 to be 170,491¾ hundredweights, and 6642 barrels—being a decrease upon the preceding year of 6608¼ hundredweights, but an increase of 325½ barrels. Of course, in addition to all this, there must be taken into consideration the very large quantity caught of which no account is taken; and the total supply may be estimated from the fact, that from our home sea-fisheries alone, we get four millions of these fish! Cod is also to be had in very large quantities in the much-neglected Irish bays; and the coasts of Norway, we are told, absolutely swarm with the members of the cod family, and profitable fisheries are carried on there in the various fiords. This fish is usually referred to as one of the most remarkable instances of animal fertility—the eggs in one female sometimes amounting to the incredible number of 9,384,000. Cuvier says that 'the flesh of these fishes, which is white, firm, and of most excellent flavour, renders them exceedingly valuable to us. It is capable of being preserved in a state fit for eating much longer than that of other species of this class. Its consumption is consequently extended through the four quarters of the globe.'

There is a large commerce carried on in other members of the cod family, chiefly, however, in haddocks and whitings, which are much esteemed in a fresh state, as also when dried and brought to market, as the well-known Finnans. The haddock is found in large numbers in all the British seas, and is taken, like the cod, chiefly by baited lines; considerable quantities are also got by the use of trawl-nets in the deep-sea fisheries. It is supposed that the very finest are to be found in the inlets and bays of the sister-island. The smoked or cured fish are prepared in a very simple way, by most of the inhabitants of our fishing-villages. They are merely split up, the intestines are taken out, and they are then hung up in the chimney-corner, to be smoked generally by means of a peat-fire; as many as from 200 to 400 can be made ready in a batch at a fire-side of ordinary size. 'The commerce in this description of fish has greatly increased in Scotland,' says Mr James Wilson, 'many having embarked in it on a large scale, by erecting extensive curing-houses, and purchasing haddocks from numerous captors, who confine themselves almost solely to this department of fishing. The whole process, when performed upon the smaller scale, and by the country-people, takes only a few hours; so that fish caught in the evening may be in a market many miles distant on the morning of the following day. The real Finnans are generally small, and of a pleasant pale-yellow colour; but larger fish are cured at the great commercial stations, and in a way intended to admit of their being sent to a longer distance, and keeping for a longer time.' The Scottish markets used to have large supplies of the haddock; the quantity taken was sometimes immense; and hundreds of people found a livelihood in hawking it about the streets, where at one time it could be purchased for a mere trifle. Even yet, it is comparatively cheap in such towns as Edinburgh. In the *Gadidæ*—the family of the cod-fish—are included the common cod, the dorse or variable cod, the haddock, the bib, the poor or power cod, the speckled cod, the whiting, the coal-fish, the pollack, the green cod, the hake, the ling, the burbot, the three-bearded rochling, and the torsk or tusk, all of them good for food.

THE FLAT-FISH OR TRAWL FISHERY.

Pleuronectidæ, the family of the flounders, or flat-fish, includes many of our most esteemed table delicacies, embracing the aldermanic turbot, the delightful sole, the halibut, as well as brill, dabs, plaice, &c. This kind of fish is captured chiefly on the English coasts, the instrument employed being the trawl-net. Trawling is a very simple way of fishing, and well adapted for the taking of flat-fish, which are mostly denizens of the deeper parts

of our coast. The net employed in this method of fishing is in the form of a large bag open at one end. It is suspended from the stern of the fishing-lugger, which drags it at a slow pace over the fishing banks.

We have not space to give a separate account of each member of the flat-fish family, but we must notice one or two of the principal varieties, giving precedence to the turbot, which is in great request, in consequence of the exquisite flavour of its flesh, and which 'has exercised the skill and ingenuity of the great professors of gastronomy, in a variety of culinary preparations, from the time of Apicius down to that of Ude and Kitchener.'

Hamilton, in his work on British fishes (1843), says: 'The ordinary length of the turbot is from eighteen inches to two feet, and the weight from four to ten pounds. Individuals of 20, 30, 70, and even 190 pounds' weight have been met with. The extent of the demand for this fish in the London market appears from the fact, that the annual supply at Billingsgate has been 87,958. A preference is given to those brought by the Dutch, who are supposed to have drawn for many years back not less than £80,000 a year for the supply of this market alone. Up to the present year (1843), a duty of £6 was paid for each boat-load, which might consist of from 100 to 150. By the recent modification of the tariff, the duty has been reduced.' The turbot is scarce in the northern waters, rare at the Orkneys, and seldom seen among the Shetland Islands. We find them, however, at the mouth of the Forth; and on the coasts of Berwick, Northumberland, Durham, and York they have been plentifully taken. When trawling is unsuccessful, the line is resorted to; and 'vast stores of turbot are found in the Silver Pits between the Dogger and Well Banks, where hundreds of vessels may be found profitably engaged in its capture.'

As we have indicated, 'our London and home markets are largely supplied by the Dutch fisheries, which commence early in the spring-season; and neither the Scotch nor English pursue the fishery with the same success as our enterprising neighbours from Holland. As the year advances, the fish migrate to where deeper water is obtained, and where the line must be resorted to. The fishery terminates about the beginning of autumn. The coasts of Devonshire, and off Dover towards the French side, are all productive places for the taking of these kinds of fish. Soles have been caught of the great weight of nine pounds, and very frequently of five pounds' weight. Skate-fishing, which is much followed in the north, is similar to the other kinds of trawl-fishing.' The skate, however, belongs to a distinct family—the rays. 'In the Firth of Forth,' according to Dr Parnell, 'these fishes are met with in great numbers, particularly in the neighbourhood of the Bass and May, where they are taken in nets, and are often found on lines set in deep water for cod. In the spring months, the Edinburgh market has a daily supply, and so great is the demand, that no less than a dozen cart-loads are sold during the week.'

The commerce in all kinds of flat fish is very considerable, as may be inferred from the fact, that 97,520,000 soles passed through the great market of Billingsgate in the year 1850; and plentiful supplies reach London without being enumerated. The turbot supply of the same year was 2500 tons. Of dabs and flounders, 91,950 pounds' weight are recorded as used in the great metropolis alone. We may judge from these figures of the quantities likely to be consumed by the busy populations of those other large towns which are fortunate enough to procure the luxury of fresh fish.

THE MACKEREL-FISHERY.

The principal seat of this fishery is Great Yarmouth, on the coast of Norfolk, already alluded to in our account of the herring-fishery. A great part of the prosperity of this town has arisen from its fisheries. In 1853, about 90 boats were engaged at this fishery, and the produce of their two months' labour realised about £30,000. When the fishing-luggers come ashore with their cargo, it is at once disposed of by auction, and despatched in all haste to London, where, of course, there is a ready market at all times for any quantity of fish. The mackerel is a voracious feeder, and its growth rapid; but it is not the largest fish that are accounted best for the table. Those taken in May or June are considered superior in flavour to such as are caught either in early spring or in autumn. The mackerel spawns in June; and 540,000 ova are said to have been counted in one female. For the mackerel while roaming at large through the waters of the ocean, no successful mode of capture could be adopted; but at its periodical return to the coasts, millions are taken by the net, seine, or line, and yet the number caught is but a mere fraction of the countless shoals that escape.

The modes of taking this fish are, in general, the same as those employed in the herring-fishery, varied by the two other methods which are thus described by Mr Couch: 'The one by means of a long deep net, with small meshes, by which the fish are surrounded, and then either taken from the water by *flaskets*, or hauled direct to the land, in the manner of a ground-net; the other by means of a hook and line, called *trailing*. The latter forms a first-rate marine sport, and is thus performed—"The mackerel will bite at any bait that is used to take the smaller kinds of fish; but preference is given to what resembles a living and active prey, which is imitated by what is termed a *lask*—a long slice cut from the side of one of its own kind, near the tail. It is found also that a slip of red leather or piece of scarlet cloth will commonly succeed; and a scarlet coat has therefore been called a mackerel bait for a lady. The boat is placed under sail, and a smart breeze is considered favourable; hence termed a 'mackerel breeze.' The line is short, but weighed down with a heavy plummet; and in this manner, when these fish abound, two men will take from 500 to 1000 in a day. It is singular that the greatest number of mackerel are caught when the boat moves most rapidly, and that even then the hook is commonly swallowed. It seems that the mackerel takes its food by striking across the course of what it supposes to be its flying prey. A gloomy atmosphere greatly aids this kind of fishing."'

SHELL-FISHERIES.

There is an immense demand by all classes for shell-fish. Lobsters, crabs, crayfish, oysters, muscles, cockles, periwinkles (whelks), prawns, and other varieties, are constantly in requisition. Most of the lobsters brought to the English market are disposed of through the agency of Mr Saunders of Thames Street, who has great quantities of this crustacean delicacy consigned to him every morning from the fishermen of Norway, France, and the Channel Islands. This gentleman, it is said, deals in shell-fish to the extent of £40,000 per annum; nearly half of that sum being due to the Norwegian branch of the trade. The following is a description of the kind of vessel used for carrying shell-fish: 'The hold is divided into compartments, and in one division may be seen hundreds of lobsters; another compartment contains sea-crayfish, and next door to them are as many crabs. All these are by degrees removed from the ship, and are kept alive and ready for the market in the *carbs*—spacious perforated trunks made for the purpose.' Orkney and Shetland also yield a part of our lobster supply; and Mr T. E. Symonds, R.N., states in a pamphlet on the Irish fisheries, that 'in no country in the world are lobsters more numerous, or in greater perfection, than on the coast of Ireland, especially the west and north-west; and if the fishery was properly worked, and means devised for preventing the capture of the young, the supply would be sufficient for all the markets of the United Kingdom that now have recourse

to foreign sources. To shew the importance of this fish to the London market, large class well-boats are sent from thence, and other English ports, expressly for the purchase of lobsters, which they procure at the rate of from 4s. to 6s. per dozen, to almost any extent; 10,000 per week are readily obtained at these prices at several places on the west coast, and the number might be doubled if, by proper and stationary appliances, the country-people were saved the trouble of sending them to market. The average wholesale price in Billingsgate is 1s. each, or £50 per 1000; though sometimes, from gales, or contrary winds, or calms, they are scarce, and realise more than double that price in that and other markets. Under the present disadvantages of carriage to the rail by *car* and *sailing-boat*, there are very heavy losses in lobsters taken on the west coast, many hundreds dying on the journey, and consequently unsaleable; and others being deteriorated, sell at a very reduced rate. . . . The Irish fish are the finest, but the voyage being longer, is not so certain, and is attended with more risk, lobster carrying being subject to the following contingencies: thunder kills them when in the well, also proximity to the discharge of heavy ordnance. Mr Scovell lost several thousands from the latter, one of his smacks having anchored at night too near the saluting-battery at Plymouth. Calms also destroy the lobsters in the well, but onward or pitching motion in a sea-way does not affect them. They keep alive one month in the well without food. The above causes have no effect on lobsters in the pond. . . . Lobsters have been constantly brought from Norway to London in a screw well-boat—a passage of 500 or 600 miles—with very few casualties; whereas, in *sailing-vessels* there are many thousands lost continually. By a return from the Midland and Great Western Railway of Ireland, it appears that 101 tons 6 hundredweights of lobsters were carried from Galway on that line during the year ending 31st December 1854, in addition to those taken by well-boats to London by sea.'

The common edible crab is too well known to require description. The most remarkable feature in its economy, and which indeed is common to all crustaceans, is the process of sloughing, or moulting at regular periods the entire calcareous covering or crust. As it is obvious that the hard shell, when once perfected, cannot change with the growth of the animal, it becomes necessary that it should be shed entirely. When the season of shedding arrives, the aquatic crabs generally seek the sandy shores of creeks and rivers, and having selected a place of rest, the change begins. The body seems to swell; the larger upper shell begins to separate from the breast or corslet; the muscles of the limbs soften and contract, which allows of their slipping from their cases; the parts about the head and antennæ undergo a similar change; and gradually the animal escapes from the crust, soft, helpless, and incapable of exertion or resistance. In twenty or thirty hours, however, a thin crust has again overspread its various parts and members, and in the course of a few days it is enabled to resume its wonted habits. During the moulting season, as well as during the period of spawning, crabs are worthless; at other times they are excellent. On the rocky coasts they frequent, they are either drawn at ebb-tide from the holes and crevices, by means of an iron hook, or they are fished for, in four or five fathoms water, by traps or cages baited with garbage. Immense numbers are annually consumed in all our seaports.

Oysters are universally known and appreciated. The principal breeding-time is in the summer months, when their spawn is usually cast: this appears at first like spots of grease, which fasten upon rocks or other hard substances that happen to be near. Very commonly they adhere to adult shells, and thus are formed the large masses called oyster-banks. In about a year and a half, the young oysters have attained a profitable size, and are then dredged up and conveyed direct to market, or are transferred to artificial pits or beds within tide reach, where they are fattened to the desired size. Though this practice of transference has been carried on from the time of the Romans downwards, it has nothing to recommend it beyond convenience, and certainty of obtaining a regular supply; for the transplanted oysters, or *exiles*, according to connoisseurs, are never found in such perfection as *natives*. As with every other article of luxury, so with oysters: certain varieties are more fashionable and popular than others. In London, the Colchester and Milton oysters are held in most esteem; Edinburgh has her 'whiskered Pandores' or Cockenzie, and Newhaven and Prestonpans oysters; and Dublin the Carlingford and Powldoodies of Burran. Swansea is also famous for its oysters. The British trade in oysters is of very considerable importance, and ranks next to that in salmon, herrings, and white fish.

FURTHER DEVELOPMENT OF THE FOOD-FISHERIES.

No less than four joint-stock companies were projected in 1856, having for their object the greater development of our fisheries. These companies are to employ steamships, and are otherwise to be adapted to the extended commercial enterprise of the present day. The prospectus of one of these companies says most truly, that 'the wealth and energies of the United Kingdom are, in other channels, rapidly developing our great industrial resources; but our fisheries remain in the same state in which they were two centuries ago. Our increasing population requires that every means that art and science can devise should be adopted, in order to procure the necessaries of life as abundantly and cheaply as possible; but though it is well known that the seas which surround the British isles teem with abundance of fish, yet the supply of that article of food is always uncertain, and its price, generally high, is often exorbitant. The British fisheries, if conducted on a proper system, and on a scale of sufficient magnitude, are capable of yielding an abundant supply of wholesome food. There is no branch of our national industry to which steam-power can be more advantageously and profitably applied. Fishing-banks as yet untouched, because they could not be reached by the present sailing-craft employed in the trade, may, by means of steam-power, be made available for a vastly increased and more regular supply of fish. Hitherto, our fisheries have been prosecuted only by the coast fishermen in sailing-vessels at particular seasons; and the principal part of the fish caught has been cured for export, or sent to London, where the demand may be said to be almost unlimited. By the adoption of steam-power, the regular and daily supply of this article of food, in the freshest state, would be extended to the principal ports of the United Kingdom, to be thence conveyed by rail to the cities and towns of the interior.'

We are also glad to see that some of these companies intend to devote their energies wholly to the extension and encouragement of the fisheries on the Irish coasts, and also to those on the west coast of Scotland. It is said that 'the seas on the west coast of Scotland, and more particularly surrounding the Western Islands, are known to possess an inexhaustible mine of wealth. Not only do they contain "greater shoals of fish than those of any other country on the globe," but they now afford peculiar facilities for making these available. Unlike the east of Scotland, the west of Ireland, or almost any other line of coast where fishing is prosecuted, the west of Scotland, in its varied mainland, its endless indentations, and numberless islands, presents a line of coast capable of being fished, extending, on a moderate computation, to upwards of 4000 miles; while its peculiarities are such as to allow of fishing being carried on at any season of the year, and in almost any kind of weather; "for there," as Dr Anderson's Report truly says, "except on the west coast of Cantyre, no wind can blow that would not admit of entering a safe harbour to leeward."'

II. THE OIL-FISHERIES.

Gas, as a means of lighting both our houses and our cities, has to a great extent rendered us independent of the use of certain kinds of oil, but, nevertheless, the varieties of sea-animals and fish from which this valuable substance can be obtained, are still in demand. In addition to the Greenland and sperm-whale fishery, we have various other sources of supply. From the liver of the valuable cod-fish, we derive an oil which occupies an important place in this country as a medicine; and the sunfish, or basking-shark, is also valuable, principally from the value of its liver. The seal also is now prized both for the sake of its skin, and because it yields a large quantity of oil.

CETOLOGY.

Even the greatest of our naturalists have been puzzled in their attempts to elucidate the natural history of the whale; and although many books have been written on the subject, the real information conveyed in them is of little moment. As one of our chief writers expresses it, 'an impenetrable veil still covers our knowledge of the cetacea;' and the late Dr Scoresby himself, who had a personal knowledge of the subject, has told us that 'no branch of zoology is so much involved as that which is entitled cetology.' Very few of those authors who have written on the whale, ever saw a living member of the species; indeed, we cannot name over half-a-dozen writers who have had any personal acquaintance with these leviathans of the deep in their own element. The most reliable authors on the subject are, Scoresby on the Greenland fishery, and Messrs Beale and Bennet on the great sperm-whale; and it is principally from these authorities that all the popular information on the natural history of the whale has been derived.

The cetaceous order of animals, of which the whale is the most remarkable and important member, is distinguished by various peculiarities, which render it a link, as it were, between the creatures of the land and the sea. While living in part or wholly in the ocean, and so formed as to make their way through its waters with ease and velocity, the cetacea differ from the true fish-tribes in being *mammalian*, or suck-giving animals; in being warm-blooded; and in having organs for respiring the atmospheric air, like the ordinary inhabitants of the land. These striking distinctive features would be sufficient in themselves to render this order of animals an object of interesting study (see ZOOLOGY); but the cetacea have also strong claims upon attention, as being of very great consequence to the wants and comforts of man. This is especially the case as regards the members of the whale family (*Balænidæ*). As the characters of the Greenland whale (*B. mysticetus*) are mostly identical with those of the whole tribe, we will direct our attention to it and to the spermaceti, as being the types of construction in the principal members of the general family, which is very numerous, embracing as it does the Greenland or right whale, the great rorqual, the cachalot or spermaceti whale, the narwhal, bottle-nose, ca'ing, and others too numerous to specify; but varying in size from the dimensions of a large cod-fish, to a length of upwards of 100 feet, and a weight of nearly as many tons.

The Greenland Whale.—Very exaggerated notions at one time prevailed as to the size of the whale, some writers asserting that 160 feet was not an uncommon length. The late Dr Scoresby, however, declared that the common whale seldom or never exceeds seventy feet in length, and is much more frequently under sixty. Out of 322 whales which he had personally aided in capturing, *not one* exceeded fifty-eight feet; and the largest ever taken, of which he knew the reported measurement to be authentic, came up only to sixty-seven feet. The greatest girth is from thirty to forty feet, the thickest portion of the animal being immediately behind the head; the head occupies a space equal to a third of the whole body. The whale is destitute of the back or dorsal fin, but possesses two pectoral fins, which are situated about two feet behind the angles of the mouth, and are nearly five feet broad by nine feet in length. The tail, which is formed in the shape of a crescent, is horizontal, and about twenty-four feet broad. It is an instrument of immense power; and the whale has sometimes given a stroke with it which has sent large boats high into the air in a thousand splinters. The colour of the body is mainly a velvety black; the under part of the head and abdomen, and the junction of the tail, being partly white, and partly of a freckled gray. The eyes of the whale are about a foot behind the angle of the mouth, and are not much larger than those of the ox. The iris is of a white colour, and the organs are guarded by lids and lashes, as in quadrupeds. The two blow-holes of the whale, situated on the summit of the head, and descending perpendicularly through it for a length of twelve inches or so into the top of the windpipe, are the only other external features worthy of notice.

The mouth of the common whale is an organ of wonderful construction, and in a large specimen it may measure, when fully opened, sixteen feet long, twelve feet high, and ten feet wide. It contains no teeth; and enormous as the bulk of the creature is, its throat is so narrow that it would choke upon a morsel fitted for the deglutition of an ox. An inch and a half is stated to be the diameter of the gullet in the very largest whales. From this peculiarity of formation, it may be anticipated that the food of the animal is of a very minute nature, notwithstanding the vastness of the cavity which is prepared for its primary reception. The animal is indeed supported upon a multitude of smaller inhabitants of the deep; and to permit this, its mouth is provided with a remarkable apparatus, composed of what is called *baleen*, the well-known *whalebone* of commerce. The baleen is arranged in two rows of laminæ, or thin plates, projecting laterally from a line in the centre of the arch of the palate, somewhat like the laminæ of a feather. There are about 300 of these plates on each side; and when dried, they weigh usually above a ton. The longest plate, which is always placed about the centre of the series on each side, measures about twelve feet in length by fifteen inches in breadth. The use of these elastic plates, with their pendulous fringes, is to retain, as in a net, the multitude of small animals which are floated into the mouth of the whale whenever it is opened. Were it not for such a drainer, formed by these fringes with the aid of the tongue, which is merely a great mass of fat tied down to the lower jaw, the emission of the water would be attended by the escape of all the objects which entered with it. As it is, the most minute matters are retained; and shrimps, sea-snails, small crabs, medusæ, beröe, &c., are thus entrapped to support the great monster of the deep.

The skin of the whale consists, first of the scarf-skin or epidermis, which is moistened by an oily fluid, enabling it to resist the action of water; secondly, of the *rete mucosum*, a layer usually held to contain the colouring matter of all animal surfaces; and, thirdly, of the true skin, which, for particular purposes, is open in texture, so as to contain the blubber, from which the oil is boiled out in great quantities. This mass—which surrounds the whole animal in a layer from one to two feet thick, and sometimes weighs more than thirty tons in all—serves the important end of keeping the animal warm by its weak conducting powers, and is also calculated to resist the enormous pressure to which the body of the creature must be subjected at the depths to which it often descends. Moreover, being inferior in specific gravity to water, it is obvious that all this body of oil must be of the greatest service in augmenting the buoyancy of the animal's frame. Below the skin are situated the muscles or flesh, which is red in colour, and tastes like coarse beef; and the character of this structure is much the same in the whale as in the ox or

horse. With the exception of the tail, the arrangement of the various muscles of the whale does not differ very much from that of quadrupeds, and the same remark applies to the osseous structure. The fins are merely rudimental arms, containing nearly the same bones as in man, and the chest strongly resembles that of ordinary quadrupeds. The vertebral column of the rorqual whale contains sixty-three bones, those of the Greenland whale are not quite so numerous. The skull consists of the crown-bone, from which the facial bones and upper jaw project forward, while the lower jaw is composed of two long curved bones, that meet at the point or forepart of the mouth. The whole of these bones are hard and porous, and some of them contain large quantities of fine oil, but they have no proper medulla or marrow.

The organs of respiration in the whale are formed upon the same principle as those of land-animals, but with modifications to suit the element in which the creature lives. It is plain that some provision was required to permit the whale to breathe, without the risk of having the lungs filled with water. This is accomplished by the extension of the top of the wind-pipe into the nostrils or blow-holes, or rather into the passage which terminates in these in the common whale. By this contrivance, the creature can inhale air while it is feeding or has its mouth full of water. As with terrestrial animals, the air gives a red colour to the blood, or, in other words, oxygenates it, and sustains the animal heat. Accordingly, the whale has frequently to come to the surface for air; but this operation is rendered less frequently necessary by the provision of a reservoir, consisting of a plexus of vessels filled with oxygenated blood, which can be drawn upon when required. The quantity of the blood, too, is great in proportion to the whole mass of the frame. The brain of the whale is held by Cuvier to be large in relation to the animal, but the arrangements of its nervous system are not understood. It is known that whales possess pretty acute vision, but there is a doubt whether or not they have any external ear. Their sense of smell seems to lie in the blow-holes; yet the strongest reason for ascribing such a faculty to them at all is founded upon the half-traditionary notion of sailors, that if certain strong-smelling substances are thrown overboard, whales will fly from the spot at once. The mammæ of the common whale are two in number, and attached to the abdomen; in the case of some other varieties, they are placed on the breast. The milk of the animal is said to be rich and creamy.

The cachalot or spermaceti whale differs from the Greenland species in having no baleen. It is much larger in size than the right whale, being frequently found to extend to a length of seventy or eighty feet, and sometimes even attaining the extraordinary dimensions of ninety and a hundred feet, from the snout to the tail. Some species of the spermaceti whale possess two, others three fins; some have the spout in the neck, others in the snout; some have flat teeth, and others sharp teeth; and the colour of the back varies between black, blue, and gray. Generally speaking, the characters now to be noticed are proper to all. The head is enormous in bulk, being fully more than a third of the whole body, and it ends like an abrupt and steep promontory in front. On the upper part of the snout is placed the blow-hole, often verging a little to one side; and it is a remarkable fact, that this is but one of the various deformities, whether congenital or acquired in the terrible battles waged by the creatures with one another, which are commonly found on the body of this whale. Its eyes are unequal, and the left frequently useless. The back has a greenish-gray tint, and below, much of the creature is white. On the back there are in most of the species one or two small fins, with large protuberances; the side fins are also of small size; but the tail is an instrument of amazing power. The teeth are usually about forty-two in number, and fit into depressions in the upper jaw. In this whale, the gullet is wide enough to admit a man, and the animal feeds on large fish. A cephalopodous mollusk (*Sepia octopus*), called *squid* by the sailors, is its chief food in deep seas.

The size of head in the sperm-whale has a very extraordinary purpose to serve. To assist in floating the animal, a great cavity in the interior of the skull is filled with a fine oil, which becomes concrete on cooling, and forms the spermaceti of commerce. Some of this oil is also found along the vertebral column; and in a bag in the intestines another valuable substance lies, the ambergris of traders. These are the principal objects of the sperm-whale fishery, the blubber procured from this variety of the cetacea not being nearly so abundant as in the case of the mysticetus. At the same time, the blubber of the sperm-whale is valuable, and is converted into sperm-oil. The sailors know this whale, at a great distance, by the act of blowing, which it performs with great regularity, at intervals of ten minutes or so. The spout sent up is visible at a distance of two or three miles, and has the appearance of a misty cloud or bush. Having thus blown sixty or seventy times, and made inspirations as often, the animal descends, and can remain under water more than an hour, subsisting on the store of blood which has been oxygenated, and is kept in the reservoirs already described. This alternation of appearances and disappearances is gone through by the animal with undeviating regularity, unless it be disturbed. The sperm-whale is timid before man, yet it fights fiercely with those of its own race. Fights usually take place when male whales, or *bulls*, as they are called, and one or two of which always attend a particular herd of females, meet with rivals desirous of entering their company. They lock jaws with one another, and exert a dreadful degree of power at one another's cost. When alarmed, or harpooned, they sometimes roll over and over on the surface of the water in an amazing manner. Still, they are not furious or dangerous towards the mariner, but are commonly killed with ease. The sailors call a herd a *school*, and the old bulls the *schoolmasters*. The females are said to be smaller than the males by a fourth. They are, like the Greenland whale, very fond of their young, and also of one another; so much so, that by cautious management, a whole herd may be destroyed, as they will scarcely quit a wounded companion.

The mode of killing these leviathans of the deep is almost always the same, and whether they are Greenland or sperm whales, the harpoon is the instrument commonly used for their destruction. Various new methods for killing the whale have been tried—such as a mortar to project shells into them, also a gun from which to fire the harpoon—but these methods have not been attended with much success.

THE SPERMACETI-WHALE FISHERY.

Some years ago, very little was known either about the natural history of the sperm-whale, or of the great value of its products to mankind. It was only when one of these mighty animals happened to be stranded, that its oil was obtained; and the valuable spermaceti, one of its products, was popularly supposed to be derived from a different source. In those days, this substance was of course exceedingly scarce, and only to be purchased at druggists' shops as an ointment or medicine. In course of time, the value of the animal came to be discovered, its haunts were eagerly sought out, fleets of ships set off to explore, and its pursuit and capture soon became a valuable source of gain, especially to the enterprising sailors of the American merchant-service.

The cachalot is certainly the largest inhabitant of the mighty deep, the most valuable to man, and the most formidable to do battle with. The substances derived

from this leviathan of the seas, are sperm-oil, spermaceti, and occasionally ambergris, which is found concealed in a bag in its intestines, or is, as some writers assert, the fœces of the animal. The South-sea whalers are vessels of about 400 tons, and are smart, well-rigged ships, manned by expert seamen, who are paid by a share of the proceeds of the fishery. They provide for a long cruise: it lasts, on the average, from three to four years; and they differ in many respects from the Greenland ships, as they carry a furnace and boilers, called *trypots*, for the purpose of extracting the oil as soon as a fish is captured. The crew averages from about thirty to forty people, including the master, surgeon, mates, harpooners, &c. The best possible arrangements are made for the health of the crew, and the vessel is always kept as clean as the nature of the business carried on will admit. Five boats are usually attached to the whaler, provided with every requisite; chief among which is the whale-line, made of fine manilla hemp, two-thirds of an inch thick. In speaking of this important part of the arrangement of a whale-ship, Herman Melville, a practical authority, says: 'In length, the common sperm-whale line measures something over 200 fathoms. Towards the stern of the boat, it is spirally coiled away in the tub, so as to form one round cheese-shaped mass of densely bedded sheaves, or layers of concentric spiralisations, without any hollow but the "heart," or minute vertical tube formed at the axis of the cheese. As the least tangle or kink in the coiling would, in running out, infallibly take somebody's arm, leg, or entire body off, the utmost precaution is used in stowing the line in its tub. Some harpooners will consume almost an entire morning in this business, carrying the line high aloft, and then reeving it downwards through a block towards the tub, so as, in the act of coiling, to free it from all possible wrinkles and twists.'

The great hunting-field for the sperm-whale is the vast Pacific Ocean. When the ship arrives on likely 'ground,' a sharp look-out is kept both for single whales and the *school*, or shoal, often to be seen led by one or two of the larger males or 'bulls.' The sperm-whales are in ordinary circumstances shy, and it requires much caution before those in pursuit can come so near a single fish as to fix it with a harpoon. They have the power of raising their heads perpendicularly out of the water to a very considerable height; and when in this attitude, which seems to be assumed for the purpose of viewing the surrounding expanse, they present the appearance of huge black rocks. They are said to have the ability, also, on noticing any object, to communicate the intelligence to their companions, though the manner in which this is done remains a secret. Mr Beale gives it as his opinion, that the sperm-whale can communicate signals to a distance of four, five, and even seven miles. This cannot be effected by sounds, for, above water at least, the animal utters no noise whatever, if we except the hissing sound accompanying the act of respiration. With regard to its other habits, the sperm-whale much resembles the Greenland whale. It is often seen, like its northern congener, to leap directly out of the water, or to *breach*, as the sailors call the action. Its purpose is to get rid of various sucking fish and crabs, which are fond of effecting a lodgment upon its mountainous body, and which often remain there till plucked from off the captured animal by the whalers. Successive watchers are stationed upon each mast-head to keep a look-out—not in a crow's-nest, like the Greenland whaler, but simply on the cross-trees, as the South-sea ships are not provided with a crow's-nest. When the magic 'There she spouts!' is sounded by the look-out, the crew start at once into a state of the greatest excitement. The boats are instantly lowered; the crew rapidly take their places, and away they pull, straining every nerve to come up with the huge leviathan before it dives. Arrived within reach of the animal, the command is given: 'Stand up, and give it to him.' The harpooner, dropping his oar, seizes his iron dart, and poising it high above his head, with unerring aim hurls it deep into the flesh of the gigantic cachalot. 'Stern all!' is now the cry, and the boat is backed out of reach of the stricken whale, while all the time the *line* is hissing over the gunwale with fierce velocity. The line runs out all its length; the boat, dragged by the whale, flies through the water, 'like a shark all fins.' As a whaleman says, 'whole Atlantics and Pacifics seem passed as they shoot on their way.' At length the line slackens, and the crew proceed to haul it in till the boat once again comes up with the whale, when dart after dart is hurled into the quivering body of the fish, the boat all the time, as a spectator has described the scene, 'alternately sterning out of the way of the whale's horrible wallow, and then running up for another fling. At length, tormented and wounded to death, the gigantic whale gets into that state known as the *flurry*, which may be described as the last dying flicker of the candle. After being "overwrapped in impenetrable and boiling spray, the whale once more rolls out into view," surging from side to side; spasmodically dilating and contracting his spout-hole, with sharp, cracking, agonised respirations. At last, gush after gush of clotted red gore, as if it had been the purple lees of red wine, shot into the frighted air; and falling back again, ran dripping down his motionless flanks into the sea.'

The next business is to tow the large carcass to the ship, where it is cut up and the blubber boiled for the purpose of extracting the oil. It is first firmly lashed to the side of the vessel, or suspended by appropriate gear from her rigging. The work of *flensing*, or cutting off the blubber or fat, must be expeditiously performed, for the hungry sharks, smelling the blood from afar, quickly surround the dead mass, anxious to obtain a meal. Thousands of these devouring monsters congregate round the ship, and in a few hours the valuable mass would be reduced to a heap of bones, were it not speedily cut into strips, and carried on board. This process is performed by the crew, who are armed with sharp-cutting spades made for the purpose. A great mass is first cut away, and then hauled on board by means of a block and tackle. The head is got into the ship in one great mass, and then comes the command: 'Haul in the chains—let go the carcass.' 'The vast tackles,' says Melville, 'have now done their duty. The peeled white body of the beheaded whale, flashes like a marble sepulchre; though changed in hue, it has not perceptibly lost anything in bulk. It is still colossal. Slowly it floats more and more away, the water round it torn and splashed by the insatiate sharks, and the air above vexed with rapacious flights of screaming fowls, whose beaks are like so many insulting poniards in the whale. The vast white, headless phantom floats further and further from the ship, and every rod that it so floats, what seem square roods of sharks and cubic roods of fowls, augment the murderous din. For hours and hours, from the almost stationary ship, that hideous sight is seen. Beneath the unclouded and mild azure sky, upon the fair face of the pleasant sea, wafted by the joyous breezes, that great mass of death floats on and on till lost in infinite perspectives.'

The spermaceti is now extracted from the head, and the preparation of the oil commences. Once kindled, the furnace gives out an intense heat, which is kept up by throwing in all the refuse matter. The apparatus for boiling is called the *try-works*, and the operation of boiling the blubber is termed *trying-out*. The harpooners, 'with huge pronged forks, pitch the hissing masses of blubber into the scalding pots, or stir up the fire beneath, till the smoky flames dart curling out of the doors to catch them by the feet. Anon the smoke rolls away in sullen heaps. To every pitch of the ship there is a pitch of the boiling oil, which

seems all eagerness to leap from the copper.' After this process, the oil is conveyed to the coolers; and, finally, it is run into the barrels or tanks; and on some fine day, the battered ship, after an absence of perhaps four years, runs to her port, and so finishes her adventures for the time.

The cachalot is seldom seen in the Greenland seas. It is spread, however, over an immense expanse of the ocean, having been captured almost everywhere between the latitude of 60° south and 60° north. The coasts of New Guinea and the adjacent archipelagoes, the shores of New Holland, Mitchell's Group, New Zealand, Navigator Isles, Ellis's Group, the shores of Peru, Chile, California, Japan, the Persian Gulf, the Chinese seas, the Moluccas, and many other regions of the ocean, abound more or less with this valuable cetaceous species.

As in the case of the Greenland fishery, bounties were given to the sperm-whalers up to 1821, when the trade was fairly left to private enterprise. In 1791, the sperm-oil imported into Britain amounted to 1258 tuns; in 1827, 5552 tuns were imported; and in 1836, the amount was 7001 tuns. One good whale will yield forty barrels of oil, and ten barrels of spermaceti are frequently taken from one head. About ten large barrels make a tun. Both sperm-oil and spermaceti bear a high price in the market, and are of great utility in various respects. Of late years, this branch of the oil-fishery has also fallen off; so much so, that in 1845 not a single vessel cleared out for it from a British port. 'This decline,' says M'Culloch, 'is a consequence partly of the growing scarcity of the whales in their old haunts, and of the greater difficulty experienced in their capture; but more of the competition of the Americans, and of the colonists in New South Wales and Van Diemen's Land. The situation of the latter gives them peculiar advantages for the prosecution of the fishery, which they now carry on to a great extent, and with much spirit and success.' In 1841, there were no fewer than 193,000 tons of shipping belonging to the United States engaged in sperm-fishing; and although it is difficult to obtain accurate statistics on the subject, it is supposed that even now, when the fish are scarcer than ever, the amount of shipping engaged in the South-sea fishery has not fallen off, but, on the contrary, has increased.

RISE AND PROGRESS OF THE NORTHERN SEA WHALE-FISHERY.

It is natural to suppose that those nations dwelling on the shores of the arctic seas would be the earliest engaged in the whale-fishery; and accordingly we find that not only did the Norwegians and other Scandinavians precede all the other nations of Europe in this perilous but profitable line of enterprise, but they also were the first introducers of it among the southern nations. The shores of the Bay of Biscay, where the Normans formed early settlements, became famous, through them, for the whale-fishing there carried on. In the same region was it first made a regular commercial pursuit, and as whales then visited the bay in great quantities, the traffic was convenient and easy. The Biscayans maintained it with great vigour and success in the twelfth, thirteenth, and fourteenth centuries. We find from the work of Noel, *Upon the Antiquity of Whale-fishing*, that in 1261, a tithe was laid upon the tongues of whales imported into Bayonne, they being then a highly esteemed species of food. In 1338, Edward III. relinquished to Peter de Puyanne a duty of £6 on each whale, levied on those brought into the port of Biarritz, to indemnify him for the extraordinary expenses he had incurred in fitting out a fleet for the service of his majesty. The Biscayans, however, soon gave up the whale-fishing, from the want of fish, which ceased to come southward, no longer leaving the icy seas. The voyages of the Dutch and English to the Northern Ocean, in order to discover a passage through it to India, though they failed in their primary object, laid open the remote haunts of the whale. The British Muscovy Company obtained a royal charter, prohibiting all vessels but theirs from fishing in the seas round Spitzbergen, under pretence that it was discovered by Sir Hugh Willoughby. The fact, however, was, that Barentz, a merchant-seaman of Amsterdam, had discovered it in 1596; and neither Dutch, Spaniards, nor Frenchmen were at all disposed to admit the justice or propriety of the claim made by the English. An extraordinary scene followed in the northern seas. The Muscovy Company sent out six or seven strongly armed vessels, which took up a position near Spitzbergen, and commenced an attack on all foreign ships that refused either to quit the region at once, or pay the very moderate toll of one-half the proceeds of their fishing! The English succeeded so far as to annoy everybody else, and to prevent themselves from taking almost a single fish, so busy were they in looking after others. All the nations of Europe remonstrated loudly through their envoys against these proceedings; but the Dutch, ever fearless at sea, sent out a strong fleet, which effectually guarded their own fishing. At length, in 1618, a general engagement took place, in which the English were worsted. Hitherto, the two governments had allowed the fishing adventurers to fight out their own battles; but in consequence of the event mentioned, it was considered prudent to divide the Spitzbergen bays and seas into fishing-stations, where the companies might not trouble each other. After this period, the Dutch quickly gained a superiority over their rivals. While the English prosecuted the trade sluggishly, and with incompetent means, the Dutch turned their fisheries to great account, and in 1680 had about 260 ships and 14,000 sailors employed in them. We are told in a little work which contains some statistics of the whale-fishery, that in the year 1697, 188 vessels, fishing in one bay, had on board the produce of 1959 whales.

After the cessation of the Muscovy Company, a Greenland Company, with an actual capital of £45,000, entered on the trade, and in nine years came to a ruinous close. In 1725, the South-sea Company took up the adventure; and in eight years, after a vast outlay, they also were compelled to submit to a dead loss of their capital, and throw up the attempt. The legislature now tried a new scheme, being sincerely desirous to encourage and establish the trade, as well as to make it a nursery for seamen. In 1732, a bounty of 30s. a ton was granted to every ship of 200 tons burden that engaged in the fishing. In 1749, it was thought necessary to raise the bounty to 40s., when, as Mr M'Culloch observes, as many ships seem to have been fitted out for catching the bounty as for catching fish. But a trade supported on any other principle than that of direct benefit received from it by the parties engaged therein, can never be of an enduring nature, and this truth soon appeared in the present case. In 1777, the bounty was reduced to 30s., the consequence of which was, that during the next five years, the number of ships employed in the trade was reduced from 105 to 39! In 1781, the bounty was raised again to its old level, and an inducement was thus held out for the revival of the spirit of trade. But after all, what a million and a half of money, expended in successive donations under the name of bounty, was totally insufficient to do, the spirit of private enterprise, once fairly awakened, speedily accomplished. The British whale-fisheries throve rapidly between 1781 and 1795; and the legislature found themselves justified in reducing the bounty, at intervals, from 40s. to 20s. In any sketch of the whale-fishery, Peterhead deserves especial mention. The Peterhead Greenland fishing commenced in 1788, and for fourteen years afterwards, one vessel per annum regularly left the port in pursuit of the

whale. In the first eight years, the produce was only six fish; but in 1798, greater enterprise began to be manifested, and some voyages produced as many as eleven whales. For many years, a considerable number of ships have left this flourishing port. In 1852, the number was 22; in 1855, 27; in 1856, 28, and in 1857, 30; some of those, however, were engaged in the seal-fishery. The provisioning alone of the fleet which left in 1857, cost nearly £16,500. The long continental troubles consequent on the French Revolution, put a complete period almost to the Dutch fishing, while in the same space of time the British fisheries were continually improving, the conduct of them being left entirely to the private spirit of the nation. A small bounty, indeed, was given even down till 1824; but it was uninfluential, and was then withdrawn altogether.

THE DAVIS' STRAIT FISHERY.

Captain Penny, the well-known whaler, informs us that the cause of the failure of the whale-fishery in Davis' Strait, is not so much from the scarcity of whales, as from the want of a proper knowledge of their habits. In former years, the whales used to be found in great abundance in north latitude 62½°, longitude 60°, at the edge of the pack. On this bank, a little north of the entrance of Hudson's Strait, they were at one time very numerous, but being so much harassed by ships, they have now almost entirely deserted this haunt. The next fishing spot frequented by the whalers was South-east Bay, in latitude 69°, longitude 55°, where whales were likewise found in great abundance; but in consequence of so many ships frequenting the place, they have also in a great measure deserted this locality; and were then followed as far north as North-east Bay, between latitude 71° and 72°, longitude 50°—the highest latitude visited by the whalers on the east side of the Strait. Of late years, however, few vessels having frequented Davis' Strait, the whales have again commenced visits to their old haunts. The above fishing-banks are those generally frequented by the whaling-vessels, from the middle of April until about the 4th of June, when the vessels proceed between the body of ice which lines the American shore in the land-water, towing, tracking, and warping* until they round the ice by Cary Islands, in latitude about 77° (a distance of 700 miles), to the next whale-fishing bank, Pound's Bay, on the American shore; and if they reach this from the end of June till about the 7th of August, when the whales are found playing by the edge of the fixed ice, a most successful fishing is generally the result.

After this period, the whale dips under the edge of the ice, and proceeds into the inlets which have become free in consequence of the great warmth which the land has now acquired. In these bays and inlets, the whales repose in perfect security, being unapproachable by whale-fishing ships. Perhaps one or two may be taken, if any of the more energetic tribes of Esquimaux happen to reside in their neighbourhood. But if a track of south-west winds set in, keeping the ice packed into the strait, preventing the ships from approaching their haunts, the fishery is then a partial failure, and the vessels have to fish down along the American shore, watching the time when the whales again take their course along the land to the south, which they generally do from the 1st of September till the 10th of October. The whales then have recourse to the deeply indented inlets of Cumberland Sound and Frobisher's Straits, feeding and playing in perfect security amongst the thousand islands, dangerous shoals, and rapid tides. The fish resort to these inlets to calve. They are sometimes to be seen in immense numbers sporting in the most frolicsome manner; and at other times, the enormous fish of 65 feet in length by 30 in breadth, with a tail 28 feet broad, leaps out of the water like a salmon, causing the spray to rise to a great distance. On these occasions, they are very watchful, and cannot be approached but with the greatest caution—the male whale making a circuit round the female to see that no enemy is approaching.

The great difficulty in the whale-fishery is to get to their haunts in season, and the only proper method of doing so is to winter beyond the barrier of ice, which extends over a breadth of 250 miles. This method has now been successfully accomplished by harbouring in a position so that the edge of the land-ice may be reached by means of sledges and dogs in the month of M[ay] with the assistance of the natives.

The Greenland Fishery has almost been a failu[re] for the last twenty years. Occasionally there are so[me] successful voyages; but the whales have been so mu[ch] harassed that they have taken shelter in the Arct[ic] Ocean, beyond those barriers of ice which lie betwe[en] Old Greenland and Spitzbergen, and between No[va] Zembla and Spitzbergen. Captain Penny, to who[m] we are indebted for much of our information on t[he] whale-fishery, says: 'There is no doubt but that beyo[nd] these barriers there is a large Arctic Ocean, which abo[ut] midsummer may extend to the north pole. And I fe[el] assured that Britain's sons, with the aid of scre[w] steamers, will yet reach, by Nova Zembla route, the ve[ry] gates of the Pacific, and return in one season wi[th] valuable cargoes of whales, where I suppose them [to] exist in thousands, reposing as yet in perfect securi[ty] from the art of man.' It is unnecessary to enter in[to] the mode of capturing the Greenland whale, as it [is] essentially the same as that of the sperm-whale alrea[dy] described.

The greatest cargo ever borne to the shores of Britai[n] by a whaling-vessel was that brought from Spitzberge[n] by Captain Souter of the *Resolution* of Peterhead, i[n] the year 1814. It consisted of 44 whales, which pr[o]duced 299 tuns of oil; value—reckoned at £32 per tu[n] the average price of that year—£9568; and whe[n] to this sum is added the value of the whalebone, an[d] the bounty, the whole would appear to have reache[d] £11,000. When oil rose to £60 per tun, smaller cargoe[s] in several instances, amounted to an equal value. I[n] 1813, the Scoresbys, father and son, respectively brough[t] home cargoes which produced £11,000. Captai[n] Scoresby, senior, in the course of twenty-eight voyage[s] captured the immense number of 498 whales, the o[il] and whalebone of which amounted in value to abo[ve] £150,000. It may be mentioned, that since the time [of] the Scoresbys, Captain Penny has adopted the practi[ce] of wintering on the station, and so making a goo[d] fishing. Thus, with his two vessels, the *Lady Frankli[n]* and *Sophia*, in 1853-4, he took forty whales, and abo[ut] 6000 seals; and the total value of his cargo reache[d] £20,000. The value of one of these monsters of th[e] deep may be considered—if a full-sized fish—to b[e] upwards of £700 or £800. The yield of oil is variable yet a good fish will give twelve to fourteen tuns, at £5[0] per tun, and one ton of whalebone, at £300 per ton which is no unprofitable concern to the owners, as well [as] to all on board.

Whale-oil is sold by the tun of 252 gallons win[e] measure, and its value fluctuates very much. Th[e] whalebone, which is next in value to the oil, is foun[d] in the mouth of the common Greenland whale. 'Whal[e]bone,' says Captain Scoresby, 'is generally brough[t] from Greenland in the same state as when taken fro[m] the fish. It is then subjected to a thorough cleansin[g] and after passing through a series of preparations, [is] ready for sale. Of late years, the price has been ve[ry] fluctuating.'

* *Tracking* is performed by the crew, who walk along the edge of the ice, and tow the ship after them: *warping* is effected by fixing the ice-anchor in a strong part of the ice several hundred fathoms ahead, when the crew on board pull the vessel towards it.

The following are the most recent statistics of the Greenland and Davis' Strait whale and seal fisheries, taken from the well-known circular of the Messrs Laurance of Peterhead:

TOTAL PRODUCE OF FISHINGS FOR EIGHT YEARS—1849-56.				
Place.	Seals.	Whales.	Tuns of Oil.	Cwts. of Bone.
Peterhead,	577,117	187	9,700	2,446
Fraserbgh.,	52,805	10	743	31
Banff, .	7,445	—	57	—
Aberdeen,	20,316	157	1,512	1,647
Dundee, .	1,090	248	2,486	3,376
Kirkcaldy,	9,005	149	1,363	1,673
Bo'ness, .	—	30	427	525
Hull, . .	117,419	167	3,124	2,311
	785,797	948	19,417	12,009

YEARLY APPROXIMATE VALUE OF PRODUCE OF FISHINGS FOR EIGHT YEARS.									
Place.	1849.	1850.	1851.	1852.	1853.	1854.	1855.	1856.	Total 8 years.
	£	£	£	£	£	£	£	£	£
Peterhead,	31,507	49,562	46,161	50,678	64,980	31,732	125,330	77,560	477,568
Fraserbgh.,	—	—	—	5,153	7,147	5,861	12,635	7,727	38,979
Banff, .	—	—	—	515	1,418	1,007	580	—	3,520
Aberdeen,	9,013	3,192	4,498	4,244	6,244	18,495	7,900	26,701	80,287
Dundee, .	30,998	13,404	18,675	12,685	11,753	6,406	2,419	31,981	123,271
Kirkcaldy,	10,129	1,864	5,088	6,692	7,978	6,504	8,016	26,048	72,319
Bo'ness, .	5,747	574	4,947	2,068	3,517	1,294	800	—	18,947
Hull, .	17,107	14,038	24,343	26,796	20,444	10,557	8,590	28,667	157,542
	101,501	83,634	98,712	108,781	123,481	81,856	166,320	198,634	972,425

As indicating the energy of the American character in the pursuit of commerce, we subjoin here a document which will illustrate the part that country takes in the Arctic whale-fishery. It is by the secretary of the United States navy:

'NAVY DEPARTMENT, *April 5*, 1852.

'In the summer of 1848, Captain Roys, of the whale-ship *Superior*, penetrated the Arctic Ocean, through Behring's Strait, and encountered in his adventurous pursuit all the dangers of an unknown and Polar Sea. He was successful in his enterprise, filling his ship with oil in a few weeks. Influenced by the report which he brought back as to the abundance of whales, owners in the United States fitted out a large fleet for these grounds; and in 1849, Captain Roys was followed by 154 sail of whale-ships, each vessel (said to be) worth on the average, with her outfit, 30,000 dollars, and manned by thirty able-bodied seamen each. This fleet took that season 206,850 barrels of whale-oil, and 2,481,600 pounds of bone. In the summer of 1850, there went up a whaling-fleet of 144 American vessels, manned as above, and of a like average value. This fleet, in the course of the few weeks left for their pursuits in those inhospitable regions, took 243,680 barrels of whale-oil, and 3,654,000 pounds of bone. . . . . The lives and property at stake there for the two years for which we have complete returns, may be thus stated:

		Dollars.	Dollars.
1849. Number of American Seamen,	4650		
Value of Ships and Outfits, . . .		4,650,000	
" " Oil taken, ...		2,606,510	
" " Bone, ...		814,112	
			8,070,622
1850. Number of American Seamen,	4320		
Value of Ships and Outfits, . . .		4,320,000	
" " Oil taken, ...		3,761,201	
" " Bone, ...		1,260,630	
			9,341,831
Total Ships in Two Years, . . .		299	
Total Seamen, ...	8970		
Value of Ships and Cargoes, ...			17,412,453

* * * *

THE SEAL-FISHERY.

Those ships that cannot obtain 'fish,' very gladly kill as many seals as possible. This branch of enterprise seems to have been originally undertaken more from sport than any other motive. The first capture of seals as a matter of commerce, of which we have an authentic account, was in 1803, when Captain Geary of the *Robert* brought home 180 along with his seven whales. Almost incredible numbers are now caught; ships have been known to bring home as many as 15,000: from 2000 to 5000 is a common number.

The vessels employed in the seal-fishery usually leave this country about the 25th of February. They are generally delayed at Lerwick (Shetland Isles) until about the 5th of March, where they engage the greater number of their crew. Seals are found in great numbers in the Greenland seas; but the principal place for hunting them is at Spitzbergen, where numerous herds of them are to be found both on the ice and on the land. They are easily wounded by means of a spear, but they are difficult to kill, and are sometimes deprived of their skin before life becomes extinct. They are chiefly valuable for their skins, and their blubber, which is cut up into small pieces and conveyed home in barrels, yields a pure and valuable oil. The statistics already given, indicate the money-value of the seal-fishery.

MISCELLANEOUS OIL-FISHERIES.

In addition to the whale and seal, oil is obtained in considerable quantities from the great sunfish or basking-shark. Considerable numbers of this fish are to be found on our coasts, and the liver of each, from which the oil is extracted, is valued at about £30.

Cod-liver oil is now well known in *materia medica* under the name of *oleum jecoris aselli*. The best is made without boiling, by applying to the livers a slight degree of heat, straining through thin flannel or similar texture. When carefully prepared, it is quite pure, nearly inodorous, and of a crystalline transparency. The specific gravity at temperature 64° is about ·920. It seems to have been first used medicinally by Dr Percival in 1782 for the cure of chronic rheumatism; afterwards by Dr Bardsley in 1807. It has now become a popular remedy in all the slow-wasting diseases, particularly in scrofulous affections of the joints and bones, and in consumption of the lungs. The result of an extended trial of this medicine in the hospital at London for the treatment of consumptive patients, shews that about 70 per cent. gain strength and weight, and improve in health, while taking the cod-liver oil; and this good effect with a great many is permanent. *Skate-liver oil* is also coming into use for medicinal purposes.

PRESERVATION OF HEALTH.

A HUMAN being, supposing him to be soundly constituted at first, will continue in health till he reaches old age, provided that certain conditions are observed, and no injurious accident shall befall. This is a proposition so well supported by extensive observation of facts, that it may be regarded as an established maxim. It becomes, therefore, important to ascertain what are the conditions essential to health, that, by their observance, we may preserve for ourselves what is justly esteemed as the greatest of earthly blessings, and dwell for our naturally appointed time upon the earth. A general acquaintance with these conditions may be easily attained by all, and to render them obedience is much more within the power of individuals than is commonly supposed.

The leading conditions essential to health are—1. A constant supply of pure air; 2. A sufficiency of nourishing food, rightly taken; 3. Cleanliness; 4. A sufficiency of exercise to the various organs of the system; 5. A proper temperature; 6. A sufficiency of cheerful and innocent enjoyments; and 7. Exemption from harassing cares. These conditions we shall now treat in succession, taking as our guides the most recent and eminent of physiological authorities.

AIR.

The common air is a fluid composed mainly of two gases, in certain proportions—namely, 20 parts of oxygen and 80 of nitrogen in 100, with a very minute addition of carbonic acid gas. (See CHEMISTRY, p. 295.) Such is air in its pure and normal state, and such is the state in which we require it for respiration. When it is loaded with any admixture of a different kind, or its natural proportions are in anyway deranged, it cannot be breathed without producing injurious results. We also require what is apt to appear a large quantity of this element of healthy existence. The lungs of a healthy full-grown man will inhale the bulk of twenty cubic inches at every inspiration, and he will use no less than fifty-seven hogsheads in twenty-four hours. And not only is this large quantity necessary, but the air that surrounds us must be in free circulation, in order that what we expire may be speedily carried away, and allowed to commingle with the atmosphere, which is subject to never-ceasing causes tending to its restoration and renewal.

Now, there are various circumstances which tend to surround us at times with vitiated air, and which must accordingly be guarded against. That first calling for attention is the miasma or noxious quality imparted to the atmosphere in certain districts by stagnant water and decaying vegetable matter. It is now generally acknowledged that this noxious quality is, in reality, a subtile poison, which acts on the human system through the medium of the lungs, producing fevers and other epidemics. A noted instance of its thus acting on a great scale is presented in the Campagna di Roma, where a large surface is retained in a marshy state. The exhalations arising from that territory at certain seasons of the year, oblige the inhabitants of the adjacent districts of the city to desert their homes, and escape their pernicious influence. All marshes, and low damp grounds of every kind, produce more or less miasma; and it is consequently dangerous to live upon or near them. Slightly elevated ground, with a free exposure to light and air, should, accordingly, in all cases be chosen for the sites of both single houses and towns. Tanks and collections of water of every kind are dangerous beneath or near a house, because, unless their contents be constantly in a state of change, which is rarely the case, their tendency is to send up exhalations of a noxious kind. Some years ago, Viscount Milton—a youth of great promise, and who had recently become a husband and father—died of a fever which was traced to the opening of an old reservoir of water underneath the country-house in which he dwelt. A similar, but more extensively fatal tragedy took place at a farmhouse in the south of Scotland. Not only did the farmer, his wife, and a female servant sink under a malignant fever, but a son and daughter, and several other servants, narrowly escaped with their lives, and only by removing from the house. It was observed in this case that removal produced instantaneous improvement of health, but a return to the devoted dwelling at once renewed the ailment. On proper investigation, it was found that immediately behind the house was a kind of millpond, into which every kind of refuse was thrown, or allowed to discharge itself; and that this collection of putrid matter had not been once cleared out for a long series of years, no one dreaming of any harm from it. The momentous consequences from a cause so trifling, and the consideration that they might have been warded off by only a little knowledge of natural causes, furnish melancholy matter for reflection. Many analogous cases, which might be referred to, demonstrate that we are yet but in the infancy of an understanding of the subject of aërial poisons.

Putrid matter of all kinds is another conspicuous source of noxious effluvia. The filth collected in ill-regulated towns—ill-managed drains—collections of decaying animal substances placed too near or within private dwellings—are notable for their effects in vitiating the atmosphere and generating disease in those exposed to them. (See No. 30.) In this case also it is a poison, diffused abroad through the air, which acts so injuriously on the human frame. This was probably the main cause of the plagues which devastated European cities during the middle ages. In those days there were no adequate provisions for public cleaning, and the consequence was, that masses of filth were suffered to accumulate. The noxious air diffused by these means through the narrow streets and confined dwellings would tend to the most fatal effects. In old drains there is generated a gas—sulphuretted hydrogen—which is calculated to produce dreadful consequences in those exposed to its inhalation. It has lately been discovered that it is the presence of this gas, arising from the shores, river deltas, and mangrove jungle of tropical Africa, which causes the peculiar unhealthiness of that region. It is ascertained that small animals, such as birds, die when the air they breathe contains one-fifteen-hundredth part of sulphuretted hydrogen, and that an infusion six times greater will kill a horse. It follows that we can scarcely attach too much importance to measures for cleaning and improving the sewerage of cities. There are as yet no large towns in Britain kept in a state so clean as is desirable for the welfare of their inhabitants; nor will they be so till the measures now in agitation for improved modes of construction, for adequate supplies of pure water, and for thorough scavengering and sewerage, be adopted.

The human subject tends to vitiate the atmosphere for itself, by the effect which it produces on the air which is breathed. Our breath, when we draw it in, consists of the ingredients formerly mentioned, but it is

in a very different state when we part with it. On passing into our lungs, the oxygen, forming the lesser ingredient, enters into combination with the carbon of the venous blood—or blood which has already performed its round through the body: in this process about two-fifths of the oxygen is abstracted and sent into the blood, only the remaining three-fifths being expired along with the nitrogen nearly as it was before. In place of the oxygen consumed, there is expired an equal volume of carbonic acid gas, such gas being a result of the process of combination just alluded to. Now, carbonic acid gas, in a larger proportion than that in which it is found in the atmosphere, is noxious. The volume of it expired by the lungs, if free to mingle with the air at large, will do no harm; but if breathed out into a close room, it will render the air unfit for being again breathed. Suppose an individual to be shut up in an air-tight box; each breath he emits throws a certain quantity of carbonic acid gas into the air filling the box; the air is thus vitiated, and every successive inspiration is composed of worse and worse materials, till at length the oxygen is so much exhausted, that it is insufficient for the support of life. He would then be sensible of a great difficulty in breathing, and in a little time longer he would die.

Most rooms in which human beings live are not strictly close. The chimney and the chinks of the door and windows generally allow of a communication to a certain extent with the outer air, so that it rarely happens that great immediate inconvenience is experienced in ordinary apartments from want of fresh air. But it is at the same time quite certain that in all ordinary apartments where human beings are assembled, the air unavoidably becomes *considerably vitiated;* for in such a situation there cannot be a sufficiently ready or copious supply of oxygen to make up for that which has been consumed, and the carbonic acid gas will be constantly accumulating. This is particularly the case in bed-chambers, and in theatres, assembly-rooms, churches, and schools. An extreme case was that of the celebrated Black Hole of Calcutta, where 146 persons were confined for a night in a room eighteen feet square with two small windows. Here the oxygen, scarcely sufficient for the healthy supply of one person, was called upon to support a large number. The unfortunate prisoners found themselves in a state of unheard-of suffering; and in the morning all were dead but twenty-three, some of whom afterwards sunk under putrid fever, brought on by breathing so long a tainted atmosphere.

Although the vitiation of the air in ordinary apartments and places of public assembly does not generally excite much attention, it nevertheless exercises a certain unfavourable influence on health in all the degrees in which it exists. Perhaps it is in bedrooms that most harm is done. These are generally smaller than other rooms, and they are usually kept close during the whole night. The result of sleeping in such a room is very injurious. A common fire, from the draught which it produces, is very serviceable in ventilating rooms, but it is at best a defective means of doing so. The draught which it creates generally sweeps along near the floor between the door and the fire, leaving all above the level of the chimney-piece unpurified. Yet scarcely any other arrangement is anywhere made for the purpose of changing the air in ordinary apartments. To open the window is a plan occasionally resorted to, but it is not always agreeable in our climate, and sometimes it produces bad consequences of a different kind.

A plan, to a considerable extent serviceable, though not perfect, for producing a draught from a room possessing a fireplace, was suggested by the philanthropic Dr Arnott. It is only necessary to make an aperture into the flue, near the ceiling of the room, and insert therein a tin tube, with a valve at the exterior, capable of opening inwards, but closing when at rest, or when a draught is sent the contrary way. The draught produced by the fire in the flue causes a constant flow of air out of the *upper part* of the room (where most vitiated); and the valve is a more or less effectual protection against back-smoke. This plan can be applied to any existing house at a mere trifle of expense. A more effectual plan, and one which operates when there is no fire in the room, is to establish a tin tube of two or three inches diameter, out of each apartment to be ventilated, causing them all to meet in one general tube, the extremity of which passes into some active flue—for example, that of the kitchen, which is rarely cold—or into any kind of channel in which an active draught can be kept up. Thus there might be a constant passing of fresh air into and through every room of a large house, so that it would be at all times as healthy in this respect as the open fields. At the same time, by means of graduated valves, both draught and supply might be regulated to any degree deemed agreeable. (For various modes of ventilation, see No. 30.)

FOOD.

The second requisite for the preservation of health is—a sufficiency of nutritious food.

Organic bodies, in which are included vegetables as well as animals, are constituted—as explained under PHYSIOLOGY—upon the principle of *a continual waste of substance supplied by continual nutrition.*

The Nutritive System of animals, from apparently the humblest of these to the highest, comprehends an *alimentary tube* or *cavity*, into which food is received, and from which, after undergoing certain changes, it is diffused by means of smaller vessels throughout the whole structure. In the form of this tube, and in the other apparatus connected with the taking of food, there are in different animals varieties of structure, all of which are respectively in conformity with peculiarities in the quality and amount of food which the particular animals are designed to take. The harmony to be observed in these arrangements is remarkably significant of that Creative Design to be traced in all things.

Man designed to live on a Mixed Diet.

Some animals are formed to live upon vegetable substances alone; others are calculated to live upon the flesh of other animals. Herbivorous animals—as the former are called—have generally a long and complicated alimentary tube, because the nutritious part of such food, being comparatively small in proportion to the whole bulk, requires a greater space in which to be extracted and absorbed into the system. The sheep, for example, has a series of intestines twenty-seven times the length of its body. For the opposite reasons, carnivorous or flesh-devouring animals—as the feline tribe of quadrupeds and the rapacious birds—have generally a short intestinal canal. The former class of animals are furnished with teeth, calculated, by their broad and flat surfaces, as well as by the lateral movement of the jaws in which they are set, to mince down the herbage and grain eaten by them. But the carnivorous animals, with wide-opening jaws, have long and sharp fangs to seize and tear their prey. These peculiarities of structure mark sufficiently the designs of nature with respect to the kinds of food required by the two different classes of animals for their support.

The human intestinal canal being of medium length, and the human teeth being a mixture of the two kinds, it necessarily follows that man was designed to eat both vegetable and animal food. As no animal can live agreeably or healthily except in conformity with the laws of its constitution, it follows that man will not thrive unless with a mixture of animal and vegetable food. The followers of Pythagoras argued, from the cruelty of putting animals to death, that it was proper to live on vegetables alone; and eccentric persons of modern times have acted upon this rule. But the ordinances of Nature speak a different language; and

if we have any faith in these, we cannot for a moment doubt that a mixture of animal food is necessary for our wellbeing. On the other hand, we cannot dispense with vegetable food without injurious consequences. In that case, we place in a medium alimentary canal a kind of food which is calculated for a short one, thus violating an arrangement of the most important nature. A balance between the two kinds of food is what we should observe, if we would desire to live a natural and healthy life.

Rules connected with Eating.

In order fully to understand how to eat, what to eat, and how to conduct ourselves after eating, it is necessary that we should be acquainted in some measure with the *process of nutrition*—that curious series of operations by which food is received and assimilated by our system, in order to make good the deficiency produced by waste.

Even in the introductory stage there are certain rules to be observed. Strange as it may appear, to know *how to eat* is physiologically a matter of very considerable importance. Many persons, thinking it all a matter of indifference, or perhaps unduly anxious to despatch their meals, eat very fast. If we are to believe the accounts of travellers, the whole of the mercantile classes in the United States of America eat hurriedly, seldom taking more than ten minutes to breakfast, and a quarter of an hour to dinner. They tumble their meat precipitately into their mouths, and swallow it almost without mastication. This is contrary to an express law of nature, as may be very easily demonstrated.

Food, on being received into the mouth, has two processes to undergo, both very necessary to digestion: it has to be masticated, or chewed down, and also to receive an admixture of saliva. The saliva is a fluid arising from certain glands in and near the mouth, and approaching in character to the gastric juice afterwards to be described. Unless food be well broken down or masticated, and also well mixed up with the salivary fluid, it will be difficult of digestion. The stomach is then called upon to perform, besides its own proper function, that which properly belongs to the teeth and saliva, and it is thus overburdened, often to a very serious extent. The pains of indigestion are the immediate consequence, and more remote injuries are likely to follow.

The importance of the saliva has been shewn in a striking manner on several occasions when food was received into the stomach otherwise than through the mouth. A gentleman, who, in consequence of a stricture in the gullet, had his food introduced by an aperture into that tube, used to suffer severely from indigestion. It is recorded of a criminal, who, having cut his throat in prison without fatal consequences, required to get his food introduced by means of a tube inserted by the mouth, that every time he was fed there was an effusion of saliva to the amount of from six to eight ounces. We cannot suppose that a fluid of a peculiar character would have been prepared in such quantity, when water would serve as well merely to moisten the food, if it had not been designed to act an important part in the business of nutrition.

With regard to mastication, the evidence of its importance is still more decided. A few years ago, a young Canadian, named Alexis St Martin, had a hole made by a shot into his stomach, which healed without becoming closed. It was therefore possible to observe the whole operations of the stomach with the eye. His medical attendant, Dr Beaumont, by these means ascertained that when a piece of solid food was introduced, the gastric juice acted merely on its outside. It was only when the food was comminuted, or made *small*, that this fluid could fully perform its function. When the stomach finds itself totally unable to digest a solid piece of food, it either rejects it by vomiting, or passes it on into the gut, where it produces an irritating effect, and is apt to occasion an attack of colic or flatulency. It must therefore be concluded that *a deliberate mastication of our food is conducive to health, and that fast eating is injurious, and sometimes even dangerous.*

The food, having been properly masticated, is by the action of the tongue thrown into the gullet. It then descends into the stomach, not so much by its own gravity, as by its being urged along by the contractions and motions of the gullet itself. The stomach may be considered as an expansion of the gullet, and the chief part of the alimentary canal. It is, in fact, a membranous pouch or bag, very similar in shape to a bagpipe, having two openings, the one by which the food is admitted, the other that by which it is passed onward. It is into the greater curvature of the bag that the gullet enters; at the lesser, it opens into that adjoining portion of the canal into which the half-digested mass is next propelled.

When food has been introduced, the two orifices close, and that which we may term the second stage in the process of digestion commences. The mass, already saturated with saliva, and so broken down as to expose all its particles to the action of the gastric juice, is now submitted to the action of that fluid, which, during digestion, is freely secreted by the vessels of the stomach. The most remarkable quality of this juice is its solvent power, which is prodigious.

The food exposed to this dissolving agency is converted into a soft, gray, pulpy mass, called *chyme*, which, by the muscular contraction of the stomach, is urged on into the adjoining part of the alimentary canal, called the *duodenum*. This is generally completed in the space of from half an hour to two or three hours; the period varying according to the nature and volume of the food taken, and the degree of mastication and insalivation it has undergone.

In the duodenum, the chyme becomes intimately mixed and incorporated with the bile and pancreatic juices; also with a fluid secreted by the mucous follicles of the intestine itself. The bile is a greenish, bitter, and somewhat viscid fluid, secreted by the liver, which occupies a considerable space on the right side of the body immediately under the ribs. From this organ the bile, after a portion of it has passed up into the adjacent gall-bladder, descends through a small duct, about the size of a goose-quill, into the duodenum. The chyme, when mixed with these fluids, undergoes a change in its appearance: it assumes a yellow colour and bitter taste, owing to the predominance of the bile in the mass; but its character varies according to the nature of the food that has been taken. Fatty matters, tendons, cartilages, white of eggs, &c., are not so readily converted into chyme as fibrous or fleshy, cheesy, and gelatinous substances. The chyme, having undergone the changes adverted to, is urged by the peristaltic motion of the intestines onwards through the alimentary canal. This curious motion of the intestines is caused by the contraction of the muscular coat which enters into their structure, and one of the principal uses ascribed to the bile is that of stimulating them to this motion. If the peristaltic motion be diminished, owing to a deficiency of bile, then the progress of digestion is retarded, and the intestines become constipated. In such cases, calomel, the blue pill, and other medicines, are administered, for the purpose of stimulating the liver to secrete the biliary fluid, that it may quicken, by its stimulating properties, the peristaltic action.

The preceding, however, is not the only use of the bile: it also assists in separating the nutritious from the non-nutritious portion of the alimentary mass, for the chyme now presents a mixture of a fluid termed *chyle*, which is in reality the nutritious portion eliminated from the food. The chyme thus mixed with chyle arrives in the small intestines; on the walls of which a series of exquisitely delicate vessels ramify in every

direction. These vessels absorb or take up the chyle, leaving the rest of the mass to be ejected from the body. The chyle, thus taken up, is carried into little bodies or glands, where it is still further elaborated, acquiring additional nutritious properties; after which corresponding vessels, emerging from these glands, carry along the fluid to a comparatively large vessel, called the thoracic duct, which ascends in the abdomen along the side of the backbone, and pours it into that side of the heart to which the blood that has already circulated through the body returns. Here the chyle is intimately mixed with the blood, which fluid is now propelled into the lungs, where it undergoes, from being exposed to the action of the air we breathe, the changes necessary to render it again fit for circulation. It is in the lungs, therefore, that the process of digestion is completed: the blood has now acquired those nutritive properties from which it secretes the new particles of matter adapted to supply the waste of the different textures of the body. (See Animal Physiology.)

When food is received into the stomach, the secretion of the gastric juice immediately commences; and when a full meal has been taken, this secretion generally lasts for about an hour. It is a law of vital action, that when any living organ is called into play, there is immediately an increased flow of blood and nervous energy towards it. The stomach, while secreting the bile, displays this phenomenon, and the consequence is that the blood and nervous energy are called away from other organs. This is the cause of that chilliness at the extremities which we often feel after eating heartily. So great is the demand which the stomach thus makes upon the rest of the system, that during and for some time after a meal, we are not in a condition to take strong exercise of any kind. Both body and mind are inactive and languid. They are so simply because that which supports muscular and mental activity is concentrated for the time upon the organs of digestion. This is an arrangement of nature which a regard to health requires that we should not interfere with. *We should indulge in the muscular and mental repose which is demanded; and this should last for not much less than an hour after every regular meal.* In that time, the secretion of bile is nearly finished; the new nutriment begins to tell upon the general circulation; and we are again fit for active exertion. The consequence of not observing this rule is often very hurtful. Strong exercise, or mental application, during or immediately after a meal, diverts the flow of nervous energy and of blood to the stomach, and the process of digestion is necessarily retarded or stopped. Confusion and obstruction are thus introduced into the system, and a tendency to the terrible calamity of dyspepsy is perhaps established.

For the same reason that repose is required after a meal, it is necessary in some measure for a little while before. At the moment when we have concluded a severe muscular task—such, for example, as a long walk—the flow of nervous energy and of circulation is strongly directed to the muscular system. It requires some time to allow this flow to stop and subside; and till this takes place, it is not proper to bring the stomach into exercise, as the demand which it makes when filled would not in that case be answered. In like manner also, if we be engaged in close mental application, the nervous energy and circulation being in that case directed to the brain, it is not right all at once to call another and distant organ into play; some time is required to allow of the energy and circulation being prepared to take the new direction. It may therefore be laid down as a maxim, that *a short period of repose, or at least of very light occupation, should be allowed before every meal.*

It is remarkable that these rules, although the natural reasons for them were not perhaps well known, have long been followed with regard to animals upon which man sets a value, while as yet their application to the human constitution is thought of only by a few. Those intrusted with horses and dogs will not allow them to feed immediately after exercise; nor will they allow them to be subjected to exercise for some time after feeding. Experience has also instructed veteran soldiers not to dine the instant that a long march has been concluded, but to wait coolly till ample time has been allowed for all the proper preparations.

Although strong mental and muscular exercise should be avoided before, during, and immediately after a meal, there can be no objection to the light and lively chat which is generally indulged in where several are met to eat together. On the contrary, it is believed that jocund conversation is useful towards the process of nutrition.

Kinds of Food.

It has been shewn, by a reference to the structure of the human intestinal canal, that our food is designed to be a mixture of animal and vegetable substances. There is, it is to be remarked, a power of adaptation in nature, by which individuals may be enabled for a considerable time to live healthily on one or the other kind exclusively or nearly so. The above is nevertheless the general rule, to which it is safest to adhere. It has been found, for instance, that field-labourers, including ploughmen, will live healthily for many years on a diet chiefly farinaceous—that is, composed of the farina of grain. But it is to be feared that the food in this case, though apparently sufficient for health, is only so apparently; and that the constitution, being all the time not supported as it ought to be, breaks down prematurely in a great proportion of instances. It has been said again that the Irish labouring-classes are a remarkably robust race, although their food consists almost exclusively of potatoes. The fact is overlooked, that the Irish eat a quantity of potatoes so enormous, as could not fail to make up in some measure for the want of animal diet. It was found by the Poor-law Commissioners, that the greater number of the peasantry of Ireland, women as well as men, take at their two daily meals in general about nine pounds-weight of this aliment! Such a case is rather to be ranked amongst instances of extraordinary adaptations to a particular variety of food, than as a proof that an unmixed potato-diet is healthy.

Climate has a remarkable effect in modifying the rule as to the mixture and amount of animal and vegetable food. The former has most of a stimulating quality, and this quality is greater in beef, and flesh in general, than in fowl or fish. Now, the inhabitants of torrid countries are, in their ordinary condition, least in need of stimulus; hence they find a simple diet of rice and sago sufficient for them. Those, on the contrary, who dwell in cold countries, need much stimulus; hence they can devour vast quantities of flesh and blubber, with scarcely any mixture of vegetable food.

Inquiries with respect to the comparative digestibility of different kinds of food, are perhaps chiefly of consequence to those in whom health has already been lost. To the sound and healthy, it is comparatively of little consequence what kind of food is taken, provided that some variation is observed, and no excess committed as to quantity. Within the range of fish, flesh, and fowl, there is ample scope for a safe choice. There is scarcely any of the familiar aliments of these kinds but, if plainly dressed, will digest in from two to four hours, and prove perfectly healthy. One rule alone has been pretty well ascertained with respect to animal foods, that they are the more digestible the more minute and tender the fibre may be. They contain more nutriment in a given bulk than vegetable matters, and hence their less need for length of intestine to digest them. Yet it is worthy of notice, that between the chyle produced from animal and that from vegetable food no essential distinction can be observed.

Tendon, suet, and oily matters in general, are considerably less digestible than the ordinary fibre; and

these are aliments which should be taken sparingly. Pickling, from its effect in hardening the fibre, diminishes the digestibility of meat. Dressed shell-fish, cheese, and some other animal foods are avoided by many as not sufficiently digestible.

Farinaceous foods of all kinds—wheat, oaten, and barley bread, oaten porridge, sago, arrow-root, tapioca, and potatoes—are highly suitable to the human constitution. They generally require under two hours for digestion, or about half the time of a full mixed meal. The cottage children of Scotland, reared exclusively upon oaten porridge and bread, with potatoes and milk, may be cited as a remarkable example of a class of human beings possessing in an uncommon degree the blessing of health. Green vegetables and fruit, however softened by dressing, are less digestible, and less healthy as a diet. One important consideration here occurs: there is need for a certain bulk in our ordinary food. Receiving nutriment in a condensed form, and in a small space, will not serve the purpose. This is because the organs of digestion are calculated for receiving our food nearly in the condition in which nature presents it—namely, in a considerable bulk with regard to the proportion of its nutritious properties. The same law applies with respect to the lower animals. When a horse is fed upon corn alone, it does not thrive. Nature did not contemplate that all horses should readily obtain a corn-diet, but looked chiefly to grass and hay for their support. She therefore prepared the organs for the reception of something of considerable volume; and when a food of less volume is persisted in, her law is violated, and fatal consequences ensue. Civilised man is disposed to pay little attention to this rule in his own case. Consulting taste alone, he is apt to refine his food overmuch, and reject what it were better for him to take. The present writer is much inclined to doubt the propriety of grinding off the coarse exterior of wheaten grain. It does not seem by any means likely that nature calculated the human alimentary cavity for the use of the white interior of the grain, exclusive of all the rest, which consists of very different but not less necessary chemical constituents. Wheat forms so large a part of our daily food, that if this be the case, we unquestionably make a departure of a very important kind from the laws of health. Experience is favourable to this view, for the effect of coarse brown bread in relaxing, seems only comparable to that of white bread in constipating the bowels.

Quantity of Food—Number and Times of Meals.

With respect to the amount of food necessary for health, it is difficult to lay down any rule, as different quantities are safe with different individuals, according to their sex, age, activity of life, and some other conditions. There is a general and probably well-founded opinion, that most persons who have the means eat too much, and thereby injure their health. This may be true, and yet it may not be easy to assign to such persons a limit beyond which they ought not to go.

The best authorities are obliged to refer the matter to our own sensations. Dr Beaumont, for example, says that we should not eat till the mind has a sense of *satiety*, for appetite may exceed the power of digestion, and generally does so, particularly in invalids; but to a point previous to that, which 'may be known by the pleasurable sensations of *perfect satisfaction, ease, and quiescence of body and mind.*'

The number and times of meals are other questions as yet undetermined. As the digestion of a meal rarely requires more than four hours, and the waking part of a day is about sixteen, it seems unavoidable that at least three meals be taken, though it may be proper that one, if not two of these, be comparatively of a light nature. Breakfast, dinner, and tea as a light meal, may be considered as a safe, if not a very accurate prescription for the daily food of a healthy person. Certainly four good meals a day is too much. No experiments, as far as we are aware, have been made with regard to the total amount of solids which a healthy person in active life may safely take in a day. It has been found, however, that confined criminals and paupers are healthiest when the daily solids are not much either above or below twenty-four ounces.* Of course, in active life there must be need for a larger allowance, but only to a small extent. We may thus arrive at a tolerably clear conviction of the reality of that excess which is said to be generally indulged in; for certainly most grown people who have the means, not excepting many who pursue very sedentary lives, eat *much more* than twenty-four ounces.

The interval between rising and breakfast ought not to be great, and no severe exercise or task-work of any kind should be undergone during this interval. There is a general prepossession to the contrary, arising probably from the feeling of freedom and lightness which most people feel at that period of the day, and which seems to them as indicating a preparedness for exertion. But this feeling, perhaps, only arises from a sense of relief from that oppression of food under which much of the rest of the day is spent. It is quite inconsistent with all we know of the physiology of aliment, to suppose that the body is capable of much exertion when the stomach has been for several hours quite empty. We have known many persons take long walks before breakfast, under an impression that they were doing something extremely favourable to health. Others we have known go through three hours of mental task-work at the same period, believing that they were gaining so much time. But the only observable result was, to subtract from the powers of exertion in the middle and latter part of the day. In so far as the practice was contrary to nature, it would likewise of course produce permanent injury. Only a short saunter in the open air, or a very brief application to business or task-work, can be safely indulged in before breakfast.

Variety of Food.

A judicious variation of food is not only useful, but important. There are, it is true, some aliments, such as bread, which cannot be varied, and which no one ever wishes to be so. But apart from one or two articles, a certain variation or rotation is much to be desired, and will prove favourable to health. There is a common prepossession respecting *one dish*, which is more spoken of than acted upon. In reality, there is no virtue in this practice, excepting that, if rigidly adhered to, it makes excess nearly impossible, no one being able to eat to satiety of one kind of food. There would be a benefit from both a daily variation of food and eating of more than one dish at a meal, *if moderation were in both cases to be strictly observed;* for the relish to be thus obtained is useful, as promotive of the flow of nervous energy to the stomach, exactly in the same manner as cheerfulness is useful. The policy which would make food in any way unpleasant to the taste is a most mistaken one; for to eat with languor, or against inclination, or with any degree of disgust, is to lose much of the benefit of eating. On the other hand, to cook dishes highly, and provoke appetite by artificial means, are equally reprehensible. Propriety lies in the mean between the two extremes.

Beverages.

The body containing a vast amount of fluids, which are undergoing a perpetual waste, there is a necessity for an occasional supply of liquor of some kind, as well as of solid aliment. It remains to be considered what is required in the character or nature of this liquor,

* See two papers on food, in Nos. 366 and 368 of *Chambers's Edinburgh Journal*, old series.

to make it serve as a beverage consistently with the preservation of health.

It is scarcely necessary to remark how men in all ages, and almost all climes, have indulged in liquors containing a large infusion of alcohol, or how widespread in our own society is the custom of drinking considerable quantities of wine, spirits, and beer, both at meals and on other occasions. Against habits so inveterate, it is apt to appear like fanaticism to make any decided objection; yet the investigator of the laws which regulate health is bound to consider, above all things, how any particular habit bears upon the human constitution, and to state what is the result of his inquiries, however irreconcilable it may be with popular prejudice or practice.

'The primary effect of all distilled and fermented liquors,' says Dr Combe, 'is to *stimulate the nervous system and quicken the circulation*.' They may thus be said to have a larger measure of the effect which animal food has upon the system. It is therefore the less surprising that those tropical nations which live most on farinaceous diet are also found to be those which have the least propensity to the drinking of ardent spirits; while those northern nations which live most on animal food have the exactly contrary inclination with respect to liquor, the Scandinavian tribes being notoriously the greatest sots that have ever been known. Dr Combe admits that in some conditions of the system, when the natural stimulus is defective, it may be proper to take an artificial supply in the form of ardent and fermented liquors. 'There are,' he says, 'many constitutions so inherently defective in energy, as to derive benefit from a moderate daily allowance of wine; and there are many situations in which even the healthiest derive additional security from its occasional use. If, for example, a healthy person is exposed to unusual and continued exertion in the open air, or to the influence of anxious and depressing watchfulness, a moderate quantity of wine with his food may become the means of warding off actual disease, and enabling him to bear up uninjured, where without it he would have given way.' But Dr Combe at the same time declares, in the most decided language, that when the digestion is good, and the system in full vigour, the bodily energy is easily sustained by nutritious food, and 'artificial stimulant *only increases the wasting of the natural strength*.' Nearly all physicians, indeed, concur in representing ardent liquors as unfavourable to the health of the healthy, and as being, in their excess, highly injurious. Even the specious defence which has been set up for their use, on the ground that they would not have been given to man if they had not been designed for general use, has been shewn to be ill-founded, seeing that *vinous fermentation*, from which they are derived, is not a healthy condition of vegetable matter, but a stage in its progress to decay. Upon the whole, there can be little doubt that these liquors are deleterious in our ordinary healthy condition; and that pure water, toast-water, milk, whey, and other simple and unexciting beverages, would be preferable—the first being the most natural—if we could only consent to deny ourselves further indulgence.

CLEANLINESS.

To keep the body in a cleanly condition is the third important requisite for the preservation of health. This becomes necessary, in consequence of a very important natural process which is constantly going on near and upon the surface of the body.

The process in question is that of *perspiration*. The matter here concerned is a watery secretion, produced by glands near the surface of the body, and sent up through the skin by channels imperceptibly minute and wonderfully numerous. From two to six pounds of this secretion is believed to exude through these channels or *pores* in the course of twenty-four hours, being, in fact, the chief form taken by what is called the waste of the system, the remainder passing off by the bowels, kidneys, and lungs. To promote the free egress of this fluid is of the utmost importance to health; for when it is suppressed, disease is ready to fall upon some of the other organs concerned in the discharge of waste.

One of the most notable checks which perspiration experiences is that produced by a current of cold air upon the skin, in which case the pores instantly contract and close, and the individual is seized with some ailment either in one of the other organs of waste, whichever is in him the weakest, or in the internal lining of some part of the body, all of which is sympathetic with the condition of the skin. A result of the nature of that last described is usually recognised as a cold or catarrh. We are not at present called on particularly to notice such effects of checked perspiration, but shall allude to others of a less perceptible, though not less dangerous nature.

The fluid alluded to is composed, besides water, of certain salts and animal matters, which, being solid, do not pass away in vapour, as does the watery part of the compound, but rest on the surface where they have been discharged. There, if not removed by some artificial means, they form a layer of hard stuff, and unavoidably impede the egress of the current perspiration. By cleanliness is merely meant the taking proper means to prevent this or any other extraneous matter from accumulating on the surface, to the production of certain hurtful consequences.

Ablution or washing is the best means of attaining this end; and accordingly it is well for us to wash or bathe the body frequently. Many leave by far the greater part of their bodies unwashed, except perhaps on rare occasions, thinking it enough if the parts exposed to common view be in decent trim. If the object of cleaning were solely to preserve fair appearances, this might be sufficient; but the great end, it must be clearly seen, is to keep the skin in a fit state for its peculiar and very important functions. Frequent change of the clothing next to the skin is of course a great aid to cleanliness, and may partly be esteemed as a substitute for bathing, seeing that the clothes absorb much of the impurities, and, when changed, may be said to carry these off. But still this will not serve the end nearly so well as frequent ablution of the whole person. Any one will be convinced of this who goes into a bath, and uses the flesh-brush in cleansing his body. The quantity of scurf and impurity which he will then remove, from a body which has changes of linen even once a day, will surprise him.

Considering the importance of personal cleanliness for health, it becomes a great duty of municipal rulers to afford every encouragement in their power to the establishment of public baths for the middle and working classes, and to extend and protect all existing facilities for washing clothes, as well as for private supplies of water. Baths should neither be very cold nor very warm, but in an agreeable medium; and they should never be taken within three hours of a meal. Nature may be said to make a strong pleading for their more general use, in the remarkably pleasing feeling which is experienced in the skin after ablution.

EXERCISE.

The constitution of external nature shews that man was destined for an active existence, as without labour scarcely any of the gifts of Providence are to be made available. In perfect harmony with this character of the material world, he has been furnished with a muscular and mental system, constructed on the principle of being fitted for exertion, and requiring exertion for a continued healthy existence. Formed as he is, it is not possible for him to abstain from exertion without very hurtful consequences.

Muscular Exercise.

With regard to merely bodily exercise, it is to be observed, in the first place, that we have no fewer than four hundred muscles, each designed to serve some particular end in locomotion, or in operating upon external objects. A sound state of body depends very much upon each of these muscles being brought into action in proper circumstances, and to a suitable extent. There is even a law, operating within a certain range, by which each muscle will gain *in strength and soundness* by being brought into a proper degree of activity.

The process of waste and renovation may be said to be always going on in the body, but it does not go on with permanent steadiness, unless the muscular system be exercised. Whenever one of the organs is put into exertion, this process becomes active, and the two operations of which it consists maintain a due proportion to each other. A greater flow of blood and of nervous energy is sent to the organ, and this continues as long as it is kept in activity. When one state of action follows close upon another, the renovating part of the process rather exceeds the waste, and an accretion of new substance, as well as an addition of fresh power, takes place. On the contrary, when an organ is little exercised, the process of renovation goes on languidly, and to a less extent than that of waste, and the parts consequently become flabby, shrunken, and weak. Even the bones are subject to the same laws. If these be duly exercised in their business of administering to motion, the vessels which pervade them are fed more actively with blood, and they increase in dimensions, solidity, and strength. If they be little exercised, the stimulus required for the supply of blood to them becomes insufficient; imperfect nutrition takes place; and the consequences are debility, softness, and unfitness for their office. Bones may be so much softened by inaction, as to become susceptible of being cut by a knife. In a less degree, the same cause will produce languor and bad health.

It is of the utmost importance to observe that the exercise of any particular limb does little besides improving the strength of that limb; and that, in order to increase our general strength, the whole frame must be brought into exercise. The blacksmith, by wielding his hammer, increases the muscular volume and strength of his right arm only, or if the rest of his body derives any advantage from his exercise, it is through the general movement which the wielding of a hammer occasions. One whose profession consists in dancing or leaping, for the same reason, chiefly improves the muscles of his legs. The right hands of most persons, by being more frequently employed than the left, become sensibly larger as well as stronger. A still more striking illustration of the principle is to be found in a personal peculiarity which has been remarked in the inhabitants of Paris. Owing to the uneven nature of the pavement of that city, the people are obliged to walk in a tripping manner on the front of their feet; a movement which calls the muscles of the calves of the legs into strong exertion. It is accordingly remarked that a larger proportion of the people of Paris are distinguished by an uncommon bulk in this part of their persons than in other cities.

In order, then, to maintain in a sound state the energies which nature has given us, and, still more particularly, to increase their amount, *we must exercise them*. If we desire to have a strong limb, we must exercise that limb; if we desire that the whole of our frame should be sound and strong, we must exercise the whole of our frame. It is mainly by these means that health and strength are to be preserved and improved. There are rules, however, for the application of these laws of our being.

1. That bodily exercise may be truly advantageous, the parts must be in a state of sufficient health to endure the exertion. A system weakened by disease or long inaction must be exercised very sparingly, and brought on to greater efforts very gradually, otherwise the usual effects of over-exercise will follow. In no case must exercise be carried beyond what the parts are capable of bearing with ease; otherwise, a loss of energy, instead of a gain, will be the consequence.

2. Exercise, to be efficacious even in a healthy subject, must be excited, sustained, and directed by that nervous stimulus which gives the muscles the principal part of their strength, and contributes so much to the nutrition of parts in a state of activity. To explain this, it must be mentioned that to produce motion requires the co-operation of the muscular fibre with two sets of nerves, one of which conveys the command of the brain to the muscle, and causes its contraction, while the other conveys back to the brain the peculiar sense of the state of the muscle, by which we judge of the fitness of the degree of contraction which has been produced to accomplish the end desired, and which is obviously an indispensable piece of information to the mind in regulating the movements of the body. The nervous stimulus thus created, will enable a muscle in the living frame to bear the weight of a hundred pounds, while, if detached, it would be torn asunder by one of ten. It is what causes men in danger, or in the pursuit of some eagerly desired object, to perform such extraordinary feats of strength and activity. In order, then, to obtain the advantage of this powerful agent, *we must be interested in what we are doing*. A sport that calls up the mental energy, a walk towards a place which we are anxious to reach, or even an exercise which we engage in through a desire of invigorating our health and strength, will prove beneficial, when more of actual motion, performed languidly, may be nearly ineffectual.

3. The waste occasioned by exercise must be duly replaced by food; as, if there be any deficiency in that important requisite, the blood will soon cease to give that invigoration to the parts upon which increased health and strength depend.

Kinds of Bodily Exercise.

Exercise is usually considered as of two kinds—active and passive. The active consists in walking, running, leaping, riding, fencing, rowing, skating, swimming, dancing, and various exercises, such as those with the poles, ropes, &c., prescribed in gymnastic institutions. The passive consists in carriage-riding, sailing, friction, swinging, &c. (For various modes of agreeable recreation, see articles on INDOOR and OUTDOOR AMUSEMENTS—Volume II.)

Walking is perhaps the readiest mode of taking exercise, and the one most extensively resorted to. If it brought the upper part of the body as thoroughly into exertion as the lower, it would be perfect, for it is gentle and safe with nearly all except the much debilitated. To render it the more effectual in the upper part of the body, it were well to walk at all times, when convenient, *singly*, and allow the arms and trunk free play. It is best to walk with a companion, or for some definite object, as the flow of nervous energy will be by these means promoted, and the exercise be rendered, as has been already explained, the more serviceable.

Very long or rapid walks should not be attempted by individuals of sedentary habits, nor by weakly persons. Their frames are totally unprepared for such violent exertion. When a person who has been long confined at still employments, finds himself at liberty to indulge his inclination for a ramble of a few days in the country, he should begin with slow and short marches, and be content therewith till his body is hardened for greater efforts. This is a rule followed in the army with respect to regiments which are about to undertake long marches. Every summer, many youths, from

ignorance, do themselves great injury, by undertaking pedestrian excursions much beyond their strength. Jaded to the last degree, and incapable of enjoying anything presented to their observation, they nevertheless persist in making out some appointed number of miles per day, never once thinking of the outrage they are committing upon themselves, and only looking to the glory of executing their task, the only pleasure they find in the journey. Serious consequences—consumption not unfrequently—follow such ill-advised efforts.

With respect to very violent walking, Dr Johnson records some effects from it, of a remarkable nature, as occurring in his own case. 'In my own person,' says he, 'I had some years ago a very severe and alarming instance of the bad effects of too great muscular action, occasioned by a habit of walking very fast. After a day and night of unusual fatigue and rapid pedestrian exertion, together with considerable mental anxiety, I was suddenly seized with an intermission of the pulse at irregular periods. During each intermission, I felt the heart give a kind of struggle, as it were, and strike with great violence against the ribs, accompanied by a peculiar and most distressing sensation in the cardiac region, which I cannot describe.' These symptoms became aggravated, and lasted for eight weeks, 'during which time,' he continues, 'I used gentle horse-exercise, and kept, when at home, in a horizontal position. At length the heart gradually lost its morbid irritability, and at the end of fourteen or fifteen weeks I could walk as well as ever.'

Running is an exercise which is intermediate between walking and leaping; it consists, in fact, of a series of leaps performed in progression from one foot to another, and the degree of its rapidity bears a constant proportion to the length of the individual and successive leaps. During this exercise, the individual is obliged to take long inspirations, and make slow expirations; the air-cells of the lungs are thereby distended, and the action of the heart being at the same time increased, and the circulation through the lungs much accelerated, a sense of oppression is felt on the chest, which is often exceedingly painful: when the violent action is discontinued, the heart palpitates with intermitting strokes, in the endeavour to recover its natural equilibrium of motion. Although this and other gymnastic exercises—such as leaping, wrestling, throwing heavy weights, &c.—may, when judiciously had recourse to, invigorate the body, yet from apprehension of the evils and accidents which may be so occasioned, young persons ought not to be permitted to engage extensively in such exercises, except under the care of some one well acquainted with gymnastics.

Fencing is, of all active exercises, that which is the most commendable, inasmuch as it throws open the chest, and at the same time calls into action the muscles both of the upper and lower extremities. Add to this that it improves very much the carriage of the body; for which reason it may be reckoned a branch of polite education. The salutary effects of the other exercises which are taught in gymnastic institutions—such as exercise with the ropes, poles, pulleys, &c.—in increasing the strength of the body, will be seen by consulting Mr Roland's Treatise on Gymnastics, where will be found a table shewing the amount of the increasing growth and strength of the body in a given time during the employment of these exercises.

Dancing is exhilarating and healthful, and seems to be almost the only active exercise which the despotic laws of conventionality permit young ladies to enjoy. We can scarcely consider modern quadrilles, elegant though they be, as exercise, seeing that they differ little from the most common walking movements. But country-dances, reels, and hornpipes, are genuine exercise, and their less refinement may be considered as amply compensated by the superior benefit which they are calculated to confer upon health.

Riding is generally classed among the passive exercises, but in reality it is one which involves much action of the whole frame, and as such is very useful. Pursued solitarily, it has the drawback of being somewhat dull; but when two or three ride in company, a sufficient flow of the nervous energy may be obtained.

The amount of bodily exercise which should be taken must vary according to the habits, strength, and general health of the individual. It was an aphorism of Boerhaave, that every person should take at least two hours' exercise in the day; and this may be regarded as a good general rule.

Mental Exercise.

Having thus explained the laws and regulations by which exercise may be serviceable to the physical system, we shall proceed to shew that the same rules hold good respecting the mental faculties. These, as is generally allowed, however immaterial in one sense, are connected organically with the brain—a portion of the animal system nourished by the same blood, and regulated by the same vital laws, as the muscles, bones, and nerves. As, by disuse, muscle becomes emaciated, bone softens, blood-vessels are obliterated, and nerves lose their natural structure; so by disuse does the brain fall out of its proper state and create misery to its possessor; and as, by over-exertion, the waste of the animal system exceeds the supply, and debility and unsoundness are produced, so by over-exertion are the functions of the brain liable to be deranged and destroyed. The processes are physiologically the same, and the effects bear an exact relation to each other. As with the bodily powers, the mental are to be increased in magnitude and energy by a degree of exercise measured with a just regard to their ordinary health and native or habitual energies. Corresponding, moreover, to the influence which the mind has in giving the nervous stimulus so useful in bodily exercise, is the dependence of the mind upon the body for supplies of healthy nutriment. And, in like manner with the bodily functions, each mental faculty is only to be strengthened by the exercise of itself in particular. Every part of our intellectual and moral nature stands, in this respect, exactly in the same situation with the blacksmith's right arm and the lower limbs of the inhabitants of Paris—each must be exercised for its own sake.

The fatal effects of the disuse of the mental faculties are strikingly observable in persons who have the misfortune to be solitarily confined, many of whom become insane, or at least weak in their intellects. It is also observable in the deaf and blind, among whom, from the non-employment of a number of the faculties, weakness of mind and idiocy are more prevalent than among other people. This is indeed a frequent predisposing cause of every form of nervous disease.

The loss of power and health of mind from imperfect or partial exercise of the faculties, is frequently observable in the country clergy, in retired merchants, in annuitants, in the clerks of public offices, and in tradesmen whose professions comprehend a very limited range of objects. There is no class, however, in whom the evil is more widely observable than in those females who, either from ignorance of the laws of exercise, or from inveterate habit, spend their lives in unbroken seclusion, and in the performance of a limited range of duties. All motive is there wanting. No immediate object of solicitude ever presents itself. Fixing their thoughts entirely on themselves, and constantly brooding over a few narrow and trivial ideas, they at length approach a state little removed from insanity, or are only saved from that, perhaps, by the false and deluding relief afforded by stimulating liquors. In general, the education of such persons has given them only a few *accomplishments*, calculated to afford employment to one or two of the minor powers of the mind, while

all that could have engaged the reflecting powers has been omitted. Education, if properly conducted, would go far to prevent these evils.

On the other hand, excessive exercise of the brain, by propelling too much blood to it, and unduly distending the vessels, is equally injurious with its disuse. And not only are fatal effects to be apprehended from undue mental task-work, but also from that constant *stretch* of the mind which attends an unduly anxious and watchful disposition. The ancients had some notion of the impropriety of an incessant exertion of the mind, and rebuked it by their well-known proverb —*Apollo does not keep his bow always bent.* But they had comparatively little experience of the oppressive mental labours endured by large portions of modern society. Irrational, and in some respects dangerous, as many of the habits of our ancestors were, it is questionable if they suffered so much from these causes as their successors do from virtuous but overtasking exertion. To maintain what each man conceives to be a creditable place in society, now requires such close and vigorous exertions, that more, we verily believe, perish in the performance of duties in themselves laudable, than formerly sank under fox-hunting, toast-drinking, and the gout.

It is in large cities that this unintentional kind of self-destruction is most conspicuously exemplified. And it is in London, above all other places, that the frenzy is to be observed in its most glaring forms. To spend nine hours at a time in business, without food or relaxation, is not only not uncommon, but an almost universal practice, among the citizens of London: from a breakfast at eight to a chop at five, they are never, to use an expressive phrase, *off the stretch.* Upon a stomach enfeebled by exhaustion, they then lay the load of a full meal, which perfect leisure would hardly enable them to digest. But far from waiting to digest it, they have no sooner laid down knife and fork, than away they must once more rush to business—not perhaps willingly, for nature tells them that it would be agreeable to rest; but then—but then business *must* be attended to. If nature were to punish the daily transgression by the nightly suffering, we should find few who, for the sake of pecuniary gain, would thus expose themselves to misery. But she runs long accounts with her children, and, like a cheating attorney, seldom renders her bill till the whole subject of litigation has been eaten up. Paralysis at fifty comes like the mesne process upon the victim of commercial enthusiasm,* and either hurries him off to that prison from which there is no liberation, or leaves him for a few years organically alive to *enjoy* the fruits of his labours.

The absurdity of an ignorance or weakness of this kind is perhaps still more striking when it occurs in individuals who make the acquisition of knowledge the chief aim of life. As the world is at present situated, it is possible to acquire learning upon almost every subject, and an infinite amount of knowledge, useful and otherwise, without even by chance lighting upon a knowledge of the most indispensable observances necessary for the preservation of a sound mind in a sound body. Half of the multiform languages of Asia may be mastered, while the prodigy who boasts so much learning knows not that to sit a whole day within doors at close study is detrimental to health; or, if he knows so much, deliberately prefers the course which leads to ruin.

The premature extinction of early prodigies of genius is generally traceable to the same cause. We read that, while all other children played, they remained at home to study; and then we learn that they perished in the bud, and balked the hopes of all their admiring friends. The ignorant wonder is of course always the greater when life is broken short in the midst of honourable undertakings. We wonder at the inscrutable decrees which permit the idle and dissolute to live, and remove the ardent benefactor of his kind, the hope of parents, the virtuous, and the self-devoted; never reflecting that the highest moral and intellectual qualities avail nothing in repairing or warding off a decided injury to the physical system, which is regulated by laws of a different, but of as imperative a nature. The conduct of the Portuguese sailors in a storm, when, instead of working the vessel properly, they employ themselves in paying vows to their saints, is just as rational as most of the notions which prevail on this subject in the most enlightened circles of British society.

It ought to be universally known, that the uses of our intellectual nature are not to be properly realised without a just regard to the laws of that perishable frame with which it is connected; that, in cultivating the mind, we must neither overtask nor undertask the body, neither push it to too great a speed, nor leave it neglected; and that, notwithstanding this intimate connection and mutual dependence, the highest merits on the part of the mind will not compensate for muscles mistreated, or soothe a nervous system which severe study has tortured into insanity. To come to detail—it ought to be impressed on all, that to spend more than a moderate number of hours in mental exercise, diminishes insensibly the powers of future application, and tends to abbreviate life; that no mental exercise should be attempted immediately after meals, as the processes of thought and of digestion cannot be safely prosecuted together; and that without a due share of exercise to the whole of the mental faculties, there can be no soundness in any, while the whole corporeal system will give way beneath a severe pressure upon any one in particular. These are truths completely established with physiologists, and upon which it is undeniable that a great portion of human happiness depends.

Repose a Condition demanded by Exercise.

Exercise demands occasional periods of repose, and, in particular, that a certain part of every twenty-four hours be spent in sleep. After having been engaged in daily occupations for fourteen or sixteen hours, a general feeling of fatigue and weakness is induced; the motions of the body become difficult, the senses confused, the power of volition or *will* suspended, and the rest of the mental faculties, becoming more and more inactive, sink at length into a state of unconsciousness. The sense of sight first ceases to act by the closing of the eyelids; then the senses of taste and smell become dormant; and then those of hearing and touch. The muscles also dispose themselves with a certain reference to ease of position, those of the limbs having grown indolent before those that support the head, and those that support the head before those of the trunk. In proportion as these phenomena proceed, the respiration becomes slower and more deep, the circulation diminishes in impetus, the blood proceeds in great quantity towards the head, and all the functions of the internal organs become retarded. In this state, shut out, as it were, from the external world, the mind still retains part of its wonted activity, deprived, however, of the guidance of judgment and the power of *distinct* recollection; in consequence of which it does not perceive the monstrous incongruities of the imagery which sweeps before it, and takes but imperfect cognizance of the time which elapses.

It may be laid down as an axiom, that the more uninterrupted sleep is, the more refreshing and salutary will be its effects; for, during this period, the body undoubtedly acquires an accession of nervous energy, which restlessness, however induced, must disturb; and therefore the state of the body before going to sleep,

* Of the frequent occurrence of premature paralysis, in consequence of the mode of life above described, we are assured by a metropolitan physician of the greatest eminence.

the kind of bed, and the manner of clothing, require especial attention. As the functions of the body are performed more slowly during our sleeping than our waking hours, a full meal or supper, taken immediately before going to bed, imposes a load on the stomach which it is not in a condition to digest, and the unpleasant consequence of oppressive and harassing dreams is almost certain to ensue. When the sleeper lies upon his back, the heart pressing, while pulsating, on the lungs, gives rise to a sense of intolerable oppression on the chest, which seems to bear down upon the whole body, so that in this painful state not a muscle will obey the impulse of the will, and every effort to move appears to be altogether unavailing. This constitutes *incubus* or *nightmare;* and it may be observed that, as acidity on the stomach, or indigestion, gives rise to such dreams, so all dreams of this disturbed character are converse indications of indigestion; for which reason, the great physiologist Haller considered dreaming to be a symptom of disease. It is certain that the dreams of healthy persons are the lightest and most evanescent.

The kind of bed on which we repose requires attention. Some are advocates for soft, others for hard beds; hence some accustom themselves to feather-beds, others to mattresses. The only difference between a soft and a hard bed is this—that the weight of the body in a soft bed presses on a larger surface than on a hard bed, and thereby a greater degree of comfort is enjoyed. Parents err in fancying that a very hard bed contributes to harden the constitution of their children; for which reason they lay them down on mattresses, or beds with boarded bottoms. A bed for young children cannot be too soft, provided the child does not sink into it in such a manner that the surrounding parts of the bed bend over and cover the body. The too great hardness of beds, says Dr Darwin, frequently proves injurious to the shape of infants, by causing them to rest on too few parts at a time; it also causes their sleep to be uneasy and unrefreshing. The universal analogy derived from other animals evinces the truth of this doctrine, both in respect to the softness and due degree of warmth of their beds. Birds line the nests of their young with feathers; the eider duck and the rabbit pluck the down from their own breast to increase the softness of the beds of their tender offspring, and brood over them with their wings, or clasp them to their bosoms for the sake of warmth. For this reason, it is better that delicate children should sleep with a bedfellow than alone; for in this case, if any part of the body becomes cold, the child instinctively places that part in contact with the warmer body of its companion. So, also, it is better for a new-born infant to sleep with its mother in winter, or with its nurse, than in a solitary crib by the bedside.

When in bed, the head should be always higher than the feet; and those subject to palpitation of the heart should lie with their heads considerably higher. Night-clothes should never consist of more than a chemise or shirt of cotton or linen, with a flannel shirt beneath. It is also highly improper to sleep in a bed overloaded with clothes; the body is thereby heated, and feverishness and restlessness induced. Accordingly, persons who complain of sleeplessness should look to the quantity of their bed-clothing; for the unnecessary addition of a single blanket may be the sole cause of the annoyance. It is also imprudent to lie with the head entirely within the bed-clothes; for in this case the same air which has been already breathed must be again and again inhaled. For the same reason, the curtains should not be drawn closely round the bed. Washing the face and hands, and brushing the teeth, before going to bed, will be found to contribute materially to comfort. Whatever be the time chosen for sleep, it is evident that no person can with impunity convert day into night. Eight o'clock for children, and eleven for adults, may be recommended as good hours for retiring to rest. It is well known that children require more sleep than adults; and more sleep is requisite in winter than in summer. The average duration of sleep which may be recommended for adults is *eight* hours; but much depends upon habit, and many persons require only six. On getting up, ablution for the sake of cleanliness and the promotion of the right action of the skin, becomes important. The washing of the entire person is desirable for these reasons; and where this cannot be effected, the cleansing of at least the face, neck, hands, and teeth, ought on no account to be neglected. The most simple powder for the teeth is finely pounded charcoal, a little of which will clear away all impurities, destroy any fetor, and preserve the teeth. On leaving the bedroom, the windows should be opened, and the clothes of the bed turned down, in order that the exhalations of the body during sleep may be dissipated. If, instead of this, the bed be made immediately after we have risen, these exhalations are again folded up with the clothes—a practice which is not consonant either with cleanliness or with health.

TEMPERATURE.

The fifth important requisite for health is, that the body be kept in a temperature suitable to it.

The degree of heat indicated by 64 degrees of Fahrenheit's thermometer, or that of a temperate summer day, is what the human body finds it agreeable to be exposed to when in a state of inactivity. In air much colder, the body experiences an unpleasant sensation, unless some warm clothing be worn, or a pretty active exercise indulged in. When, either by natural or artificial means, the body is kept in a suitable state of warmth, the functions of the circulation and perspiration in the skin go on healthily; it is red, in consequence of the blood being urged into the capillaries or minute vessels near the surface; it is also soft and moist, from the action of the glands for secreting the waste fluid and its free egress through the pores. This is a condition of great comfort; and the appearance of those who enjoy it, conveys to others the notion that they are in good health. When, on the contrary, there is a much lower temperature, the functions of the vessels connected with the skin are liable to be considerably deranged. The vessels, in these circumstances, contract; the blood is driven inwards, where it sometimes occasions diseases of a dangerous nature; the perspiration also being prevented from passing out by its usual channels, catarrhal complaints ensue, sometimes ending in consumption.

It is of the more importance to make these facts generally known, as a notion prevails that exposure to a painful degree of cold tends to induce hardiness of constitution and to promote health. Undoubtedly there may be harm from an opposite extreme, and we know well that excessive clothing and living in overheated apartments are detrimental to health. But safety lies in a medium between the two extremes. There is a degree of warmth which is both agreeable and healthy, and which it is desirable to have around us as constantly as possible—generally from 60 to 64 degrees Fahrenheit.

There is no period of life at which warmth is of more consequence than in infancy. In a very young babe, the circulation is almost altogether confined to the surface, the internal organs being as yet in a very weak state. In such circumstances, to plunge the child into cold water, from an idea of making it hardy, as is customary in some countries, and among ignorant persons in our own, is the height of cruelty and folly; for the unavoidable consequence is, that the blood is thrown in upon the internal organs, and inflammation, bowel-complaints, croup, or convulsions, are very likely to ensue. A baby requires to be kept at a temperature above what is suitable to a grown person; it should be warmly, but not heavily clothed; the room where it is kept should be maintained at a good, but not oppressive

heat; and it should never be put into other than tepid water. It should not be exposed to the open air for some days after its birth.

At all periods of life, it is most desirable to avoid exposure to very low temperatures, especially for any considerable length of time. To sit long in cold school-rooms or work-rooms, with the whole body, and especially the feet, in a chilled condition, is very unfavourable to the health of young people. It is not possible that a condition so adverse to the healthy action of the cutaneous vessels should not lead, if long persisted in, to very bad consequences. Those who are compelled to be sedentary, should make it their endeavour to obtain a sufficiently high temperature, either by warming their apartments sufficiently, or thickening their clothing. Common fires, though delightful from their cheerful look, are confessedly very inadequate, in most circumstances, to heat large work-rooms, school-rooms, or even the larger class of sitting-rooms; not to speak of the great objection which has been made to them on the score of economy, three-fourths of their heat being sent off through the chimney. It is most desirable that some means in which the public could have confidence were devised for thoroughly, and at the same time healthily, warming large apartments. Stoves enclosed in large iron-plate cases (Arnott's stoves), pipes of hot water or of steam, and blasts of heated air, are amongst the most conspicuous plans tried within the last few years. (See WARMING, No. 30.)

Clothing should be in proportion to the temperature of the climate and the season of the year; and where there are such abrupt transitions from heat to cold as in our own country, it is not safe ever to go very thinly clad, as we may in that case be exposed to a sudden chill before we can effect the proper change of dress. Very fatal effects often result to ladies from incautiously stepping out of heated rooms in the imperfect clothing which they ludicrously style *full-dress:* all such injuries might be avoided by putting on a sufficiency of shawls or cloaks, and allowing themselves a little time in the lobby to cool. The under-clothing in this country should be invariably of flannel, which is remarkably well calculated to preserve uniformity of temperature, as well as to produce a healthy irritation in the skin. While the value of comfortable clothing is fully acknowledged, we should never lose sight of the value of exercise for keeping up a kindly glow upon the surface, and for the support of a high tone of general health. Any one who, neglecting this, should live constantly in a warm apartment, or only go out of doors muffled up in a mass of clothing, would speedily suffer from a relaxed state of the system, and become so susceptible of damage from the slightest change of temperature in the atmosphere, that the most dangerous consequences might be apprehended.

Wet clothes applied to any part of the body, when it is in an inactive state, have an instantaneous effect in reducing the temperature, this being an unavoidable effect of the process of evaporation which then takes place. Hence it is extremely dangerous to sit upon damp ground, or to remain at rest for a single minute with wetted feet, or any other part of the body invested in damp garments. Dampness in the house in which we live has the same effect, and is equally dangerous. The chill produced by the evaporation from the wetted surface checks the perspiration, and sends the blood inwards to the vital parts, where it tends to produce inflammatory disease. Few persons seem to be aware of these truths. We find young men heedlessly getting their feet wet, and sitting with them in that condition, thereby incurring the most deadly peril. Young women commit a similar folly when they walk out in thin shoes in a wet or cold day. Exposure to wet, damp, or cold, is of comparatively little moment when the body, by a course of exercise or training, has been prepared to endure these conditions. Thus a person brought up delicately, or much within doors, would be killed by that which would have little or no effect on a ploughman. It is therefore worthy of being suggested as a line of policy, that no one should accustom him or her self to a pampered or too delicate mode of life. Every one should, if possible, go out daily, both in good and bad weather, with clothing corresponding to the nature of the weather, and in this way strengthen and harden the constitution to endure all ordinary and reasonable exposure. It is important, however, to note, that even the hardiest persons are never safe from the effects of wet clothes and other modes of exposure to a reduced temperature. No complaint is more common among out-of-door labourers, and also poor people in damp lodgings, than rheumatism. This is an affection produced solely by a violation of the natural law which demands that the body should not be chilled. Rheumatism is produced alike from exposure to a shower or to a draught of cold air when the body is warm, and from sitting with the feet on a cold stone or clay floor; the only difference, perhaps, being, that the rheumatism is in one case in the shoulders, and in the other in the legs. Let us therefore impress on all the propriety of avoiding chills, the effects of which may be much more fatal than a simple attack of rheumatism. When rheumatism has been contracted, the best remedy for its expulsion, if adopted in time, is friction of the part; if well rubbed before a fire with flour of mustard, so as to cause a counter-irritation on the surface, the internal complaint may be expelled.

Errors in Dress.

This is perhaps the most appropriate place in which to introduce some remarks upon errors in dress. The integuments which nature calls upon us to put on for the sake of warmth, are too often made the means of inflicting serious injury, either through ignorance, fashion, or caprice. It is therefore necessary, in a treatise on the preservation of health, to advert in emphatic terms to this subject.

It is scarcely too much to say that there is no part of the human frame, from the sole of the foot to the crown of the head, which has not been, and is not at this moment, mistreated by fashion. We laugh at the Chinese ladies, who have their feet constrained by iron moulds into mere bulbous appendages to the limbs; but we never reflect that, amongst ourselves, errors only inferior in degree are constantly committed. The foot naturally spreads out, fan-like, from the heel to the toes. But instead of having our shoes formed in the same triangular shape, they are made in a lozenge form, truncated at the front, the toes being thus perverted from their radiating arrangement into one exactly the opposite; so that they become crushed under one another, and deprived of a great part of that muscular power by which they were designed to propel our bodies in walking. In the greater height usually given to the heels of shoes, another important deviation from nature is committed. When the heel is raised above the level of the ball of the foot, a complete derangement takes place in the muscles of locomotion; the power of the limb is impaired; and the whole body is thrown off its equipoise. It is impossible, in such circumstances, to exercise the body as it ought to be. The foot is also forced or plugged down into the narrow front of the shoe, where the toes become liable to the grievance of corns. Thus the free healthy play of the various parts of the body is further diminished. From the uneasiness and constraint experienced in the feet, sympathetic affections of a dangerous kind often assail the stomach and chest; as hemorrhage, apoplexy, and consumption. Low-heeled shoes, with a sufficiency of room for the toes, would completely prevent all such consequences.

An improved taste in the male sex has long since abolished the coarse and self-annoying absurdity of

leathern small-clothes; but it is still too common to impede the circulation and the play of the muscles by tight apparel, especially in the regions of the stomach and neck. The immediate effect of these injudicious appliances is much inconvenience: the remote result is a diminution of the general strength and health. But all the errors of the male sex sink into insignificance when compared with one to which the fair are liable. In the construction of the human chest, nature has provided ample room for several important viscera, the functions of which cannot be in any degree disturbed without a wrong being inflicted upon the whole system. Here reside the heart, the lungs, the liver, and the stomach. Fine ladies may affect to shut their mind's eye to the existence of such things; but the daintiest of their emotions depend upon the right state of those very viscera, without which they could no more think, speak, and act, than they could cast languishing looks without eyes, or melt our hearts by witching minstrelsy without a tongue and fingers. In order to reduce themselves to an ideal standard of girth, almost all the unmarried, and not a few of those who are otherwise, brace themselves in a greater or less degree with corsets, which produce the desired roundness and slenderness at the expense of all the internal organs upon which health depends. The false ribs are pressed inwards; the respiratory and circulatory systems are crushed and thrust out of their proper place; the alimentary system is deranged; and even upon the exterior of the person, deformities of the most glaring kind, such as humped shoulders and curved spines, are produced. Custom to a certain extent enables the victim to endure the inconvenience: there are even some who feel so little trouble from it, as to deny that any harm ensues from tight-lacing. But a violation so excessive cannot be otherwise than mischievous. We have seen a young lady's sash which measured exactly twenty-two inches, shewing that the chest to which it was applied had been reduced to a diameter—allowing for clothes—of little more than seven inches!

All who are aware of the internal organs at that part of the body, know very well that it is impossible for these to exist in their natural condition within so small a space. Bruised, impeded, and disordered, they must of course be, and accordingly cannot fail to become a source of dreadful suffering to the wretched being who outrages them. Palpitations, flushings, dyspepsy, determination of blood to the head, and consumption, are among the evils which physicians enumerate as flowing from this sacrifice to vanity. Another of a moral kind is acknowledged to be of by no means infrequent occurrence: in order to soothe the painful sensations produced by the constraint, spirituous liquors and cordials are resorted to, and thus habits of the most degrading nature are formed. Another evil still, respecting which a hint may be sufficient, is the unfitting of the system for the duties of a mother. How many domestic afflictions, which are submitted to in a spirit of resignation, as the unavoidable decrees of Providence; how many of the saddest scenes which this world ever presents—gentle and tender girls pining away under the eyes of hopeless parents—beloved wives torn from the arms of husbands and children at the very moment when prolonged life was most needful—must be owing to a cause too trivial and unworthy to be mentioned in the same sentence with its so dire effects! No doubt, it is well to submit meekly to such afflictions; but while they are ascribed in all humility to a Providence which is upon the whole only another term for Mercy and Justice, let us not be blind to the fact, that they accrue through violations committed by ourselves upon laws established by Providence for our happiness, and might have been avoided by a different course of conduct.

The fashion of tight-lacing obviously owes its origin to a desire on the part of the ladies to attract admiration. It is of little importance to point out that they are quite wrong in their calculations as to the effect; but we would press upon the guilty parties, and all interested in their welfare, that tight-lacing is a practice which cannot be long persisted in without the most disastrous consequences. It is painful to reflect that in some instances, parents, so far from discouraging the practice, are so ignorant as to force it upon their children. We have heard of a young lady whose mother stood over her every morning with the engine of torture in her hand, and, notwithstanding many remonstrative tears, obliged her to submit to be laced so tightly as almost to stop the power of breathing. The result is, that the unfortunate victim is now severely afflicted with asthma, and has fallen into a state of low health. As a general rule, it cannot be too strongly impressed upon those who have the care of young persons, that all clothing should sit lightly upon the figure, so as to allow of the full play of every part of the system.

INNOCENT ENJOYMENTS.

A sufficiency of innocent enjoyments has been set down as the sixth requisite towards the preservation of health. It may seem almost superfluous to treat this part of the subject, since the disposition to take amusement is one by no means generally wanting. A regard, however, for the completeness of our little treatise, induces us to make a few remarks on it; and we are not satisfied that there is not a considerable number of persons to whom an injunction to take innocent enjoyments is needful. There may be some advantage, therefore, in seeing the matter placed on something like a philosophical basis.

No physiological doctrine seems more entitled to faith and regard, than that a harmonious exercise, in moderation, of all parts of the system, including the organs of the mental faculties, is necessary for health. It is proved by the very craving which we experience, after a long task, or a long perseverance in some particular habits, for something which will engage a different set of faculties. There is nothing which will pleasingly engage our thoughts for any considerable length of time. Something inferior will invariably be preferred, if it only be new. Now, the duties by which men in general earn their subsistence, are in all cases of such a nature as only to call into exercise a part of their mental and bodily system. Something is required at once to soothe and compensate us for the drudgery of our current labours, and to bring into exercise those parts of our muscular frame and intellect which professional duty has left unoccupied. To begin with a humble illustration: how delightful to a tailor, after long exercising his fingers and arms alone at his business, to enter into some athletic sport upon the village-green, by which his limbs also will be exercised! After a lawyer has fagged for a day at a brief, how delightful to be able, by the reading of a new novel or play, to call up another set of the intellectual powers! In these changes from grave to light occupation, there is at once repose given to the tasked faculty, and the gratification of employment given to others which have been pining for want of something to do. It so happens that, from the sentient nerves being mixed with those which direct the operations of all our organs, each organ has a sense of enjoyment in being rightly exercised. Even the stomach has, from this cause, a gratification when its functions are going on well, and this altogether independent of any pleasure we may have had in eating the meal upon which it is now employed. An organ left long unoccupied is thus somewhat like a child in a family which its parents have been overlooking. It craves to be noticed like the rest, and when the desired notice at length comes, it experiences a high degree of satisfaction. In short, variation of occupation and pursuit, for the purpose of keeping all the parts of the system in harmonious exercise and in healthy tone, is

one of the most important principles concerned in the preservation of health.

There are several powers of the mind which must have been designed for the express purpose of creating and receiving amusement, and the existence of which, therefore, shews that amusement has a place in the right economy of human life. The imitative arts in general—music, fiction, drollery of all kinds—spring directly from primitive faculties of the mind; and when we see the pleasure they give in society, we cannot doubt that they are things naturally required by man, and in which it is quite legitimate for him to indulge within moderate bounds and in circumstances compatible with innocence. These things are doubtless designed to alleviate the burdens of life and beguile us of its cares. They furnish something like a different sphere of existence, into which we may enter and temporarily lose the sense of all that harasses us in the ordinary one. The *joculator*—under which name our ancestors associated the poet, tale-teller, and mimic, and which we may apply equally extensively to the poet, novelist, artist, and player—is therefore a most useful functionary in society. We say nothing on the present occasion of the refinement to be derived, in addition, from communion with the productions of the higher class of such minds.

Amongst amusements, *reading* takes a most distinguished place; for there is none which may be more readily or more innocently indulged in, and fortunately, in our own country, it is one which may now be enjoyed by all. It is unquestionably the chief of indoor amusements; and few scenes are calculated to awaken more agreeable feelings in a well-constituted mind, than a family group assembled in their parlour, to hear some one of their number reading a pleasant book. Ever honoured be the great masters of fiction, who have allowed us, by these means, to pass from common life, for a time, into 'the tale of Troy divine,' the story of 'the gentle lady married to the Moor,' the tear-compelling fate of Ravenswood, and all the other numberless suppositions of things done, and persons who spoke and acted, which we feel to be more real than much of even the life that is passing around us!

Next to reading stands *music*, a means of enjoyment of which only a few comparatively, in our country, take advantage, but which might easily be made much more extensively available, and probably will be so in the course of a few years. Connected intimately with music is *dancing*, which is not only a cheerful amusement, but a positive and direct means of bodily exercise. A family musical or dancing scene, like a family reading scene, is a thing beautiful to look upon. There is a prejudice against both in some minds, on account of their being liable to abuse; but the abuses of both arise very much from their not being extensively or freely indulged in. Were music the general accomplishment which it might easily be made, it would not only be indulged in on all occasions with simplicity and innocence, but it would supplant coarser and more clandestine amusements. Dancing is the nightly amusement of the French peasantry, and it has never been pretended that these people are less virtuous than the corresponding class in our own country. *Theatrical representations* it might be more difficult to place on such a footing as to secure the unhesitating approbation of the good; but certainly if this were done, they might prove highly serviceable in furnishing amusement.

In the class of amusements, we must reckon meetings or promenades in ornamental grounds, excursions into the country, and little tours, all of which are highly commendable in those who are able to indulge in them. The entertainment of little parties of friends, and the going out to entertainments given by them in return, are other means of amusement common in society, and which may be moderately indulged in with much advantage. In short, whatever gives a pleasant variation to the monotony of life, without leading the mind away from duty or corrupting the manners, ought to be indulged in as freely as circumstances will permit. The mind returns from such diversions with renewed tone and power, and neither the time nor the expense is lost in the long-run. It is the more necessary to impress these maxims, as many well-meaning persons, alarmed perhaps at the occasional abuse of such enjoyments, repudiate them nearly altogether, and thereby lower the tone of their health, both as respects the body and the mind. It is particularly distressing to see such persons exercising a control over the young, and denying to their unfortunate protégés an element of life not much less pressingly necessary than the air they breathe. (See INDOOR AMUSEMENTS.)

Dr Southwood Smith, in his excellent work, *The Philosophy of Health*, has pointed out that pleasure is the ordinary, and pain in all cases an extraordinary, result of the action of our organs. 'There are,' he says, 'many cases in which pleasure is manifestly given for its own sake; but in no case is the excitement of pain gratuitous.' Pain is always a punishment; and, when it reaches a certain extreme, it is destructive of what feels it. But 'all such action of the organs as is productive of pleasure is conducive to the perpetuation of life. There is a close connection between happiness and longevity. Enjoyment is not only the end of life, but it is the only condition of life which is compatible with a protracted term of existence. The happier a human being is, the longer he lives; the more he suffers, the sooner he dies: to add to enjoyment, is to lengthen life; to inflict pain, is to shorten the duration of existence.' It may fairly be presumed, then, that a certain amount of enjoyment in life is necessary for health, and that when the quantity actually secured is much below that point, unhealthy conditions must ensue. If, for example, poverty or embarrassed circumstances press so severely upon a cautious and conscientious man, as to leave him scarcely a moment's comfort from one year to another, he cannot fail to sink in health. If married to a female of bad temper, or who afflicts him by bad habits, and if, from these causes, he rarely enjoys a moment of happiness, so also must his health fail. In short, to be placed in any such circumstances as constitute a bar against nearly all enjoyments, must prove injurious, and tend to the shortening of life.

Enjoyments are of many kinds. Some are sensual, as the taking of agreeable food; others are intellectual, as agreeable music, reading, &c.; others are moral, as the exercise of philanthropy, the religious feelings, &c.; and some are sympathetic, and consist in the exercise of the affections, and the reflection of that gratification which we have endeavoured to impart to others. We may consider as such all things over and above the plainest unrelished fare, and the supply of water, air, and a barely sufficient temperature. These are usually considered as strictly the *necessaries* of life, the others being the comforts or luxuries. The distinction is not quite correct. The first class are certainly immediately necessary to the support of life; that is to say, they are hourly, daily necessary. But more or less of what are called the comforts of life are also necessary, if we would preserve health. The only difference is, that the want of them would not tell in so short a time as the want of the so-called necessaries. If a human being be shut up in a cell, and allowed only a sufficiency of unrelished and unvaried food, with air and water, the want of all the enjoyments of life, sensual, intellectual, moral, and sympathetic, will, in a certain time, make him utterly miserable; the health of body and mind will give way; and if the experiment be sufficiently protracted, he will perish. The ignorance which prevails on this point has led to the trial of what is called the *silent system* in prisons, which is now about to be abandoned as utterly irreconcilable with humanity. It were well if more knowledge prevailed on the subject, for, from erroneous

ideas of what is *necessary* for healthy life, many deprive themselves or others of things which, when we take the element of time into account, are as essential to health as the supply of the air we breathe. There is, in some enthusiastic minds, a spirit of asceticism and self-mortification which would give up all the enjoyments of life together. Such persons rarely fail to reduce their own health, if they do not also exercise some unhappy control to the same effect over their fellow-creatures. While self-denial for moral purposes is always admirable, and over-indulgence of every kind saps the vigour and fortitude of the human character, it should be ever kept in view that there is great danger in reducing the allowance of comforts and indulgences too low. Very rigid views of what is necessary for the support of life usually prevail, wherever the affluent have to dictate a style of living for the poor. The tendency there is, to reduce allowances as nearly as possible to what may be called the *immediate necessaries;* for it does not seem just or right that paupers, adults or children, should enjoy any species of gratification. But these are short-sighted views. The health of these unfortunate persons requires something more, and this something would be granted by an enlightened humanity. We have a strong manifestation of this need in the eagerness with which paupers generally desire allowances of tea or tobacco, or, indeed, the least variation of their diet. The craving for these luxuries is not so much, what it is generally thought solely to be, the result of bad habits long indulged in, as it is the expression of a want in the personal economy —a want which, by one means or another, must be supplied, or injurious consequences will ensue.

Exemption from Harassing Cares.

It is little more than a repetition of doctrines already laid down, that, for the due preservation of health, a human being requires an exemption from acute distress of mind and harassing cares.

Mental distress and anxiety operate through the brain upon the condition of the whole body, and, when long protracted, effectually undermine the health. 'It is impossible,' says Dr S. Smith, 'to maintain the physical processes in a natural and vigorous condition, if the mind be in a state of suffering. Every one must have observed the altered appearance of persons who have sustained calamity. A misfortune, that struck to the heart, happened to a person a year ago: observe him some time afterwards—he is wasted, worn, the miserable shadow of himself; inquire about him at the distance of a few months—he is no more.' It is Dr Smith's opinion, that the nearest cause of many suicides is not strictly a desire to escape from a state of suffering, but some disease, probably inflammation of the brain, brought on by distress of mind. 'By a certain amount and intensity of misery, life may be suddenly destroyed; by a smaller amount and intensity, it may be slowly worn out and exhausted. The state of the mind affects the physical condition; the continuance of life is wholly dependent on the physical condition; it follows that, in the degree in which the state of the mind is capable of affecting the physical condition, it is capable of influencing the duration of life.'

Depression of mind, besides its immediate effect on the nervous system, deranges the respiration, and mars the proper oxygenation and circulation of the blood. A diminished vitality is the consequence, often leading to pulmonary consumption. An excessive agitation and alarm of the selfish feelings, such as takes place in some minds on the approach of an epidemic, affects the whole system in such a way as—to use an expressive phrase of Dr Combe—'places it on the brink of disease;' and hence the notoriously great liability of persons in this state of alarm and apprehension to fall victims to the malady when it comes. It has been remarked that an army in a high state of confidence and cheerfulness after a victory, has a much smaller proportion of sick than in the opposite circumstances, or even in its ordinary condition. The usual proportion of sick in a garrison quartered, during peace, in a healthy country, is five per cent.; during a campaign, when there is more anxiety of mind, it is ten; in the event of defeat, although the circumstances be otherwise not unfavourable, the proportion rises to a much higher amount. It is a very instructive fact, that in a large detachment of the French army cantoned in Bavaria immediately after the battle of Austerlitz, the proportion of sick was little more than *one* per cent.

GENERAL OBSERVATIONS.

The fundamental principle of every effort to improve and preserve health has been thus stated: 'Man, as an organised being, is subject to organic laws, as much as the inanimate bodies which surround him are to laws mechanical and chemical; and we can as little escape the consequences of neglect or violation of those natural laws, which affect organic life through the air we breathe, the food we eat, and the exercise we take, as a stone projected from the hand, or a shot from the mouth of a cannon, can place itself beyond the bounds of gravitation.' To this it may be added, that 'all human science, all the arts of civilised man, consist of discoveries made by us of the laws impressed upon nature by the Author of the universe, and the applications of those laws to the conditions—which are laws also—in which man and the particular bodies and substances around him are placed; nor, it is manifest, should any science concern us more than that which relates to the conditions on which organic life is held by each individual.'

The preceding sections are but explanations, such as we have been able to afford, of the conditions under which the organic frame of man exists, and the agencies, internal and external, which operate upon it, for the maintenance of health or the introduction of disease. It must be evident, where there is a conviction of the truth of the fundamental doctrine, that individuals and societies have their health very much at their own disposal; that a careful avoidance, on the one hand, of what is noxious, and a judicious attention to what is beneficial, are what are chiefly necessary for the preservation of the human frame in health to old age; and that premature deaths, over and above those which result from unforeseen casualties, instead of being, as supposed by the untutored mind, a mysterious and irreversible decree of Providence, are simply the natural effect of our own violation of laws which Providence has appointed for our welfare. It might still be objected that human nature is such, that the due obedience and observance of those natural ordinances are not to be expected; so that the vast quantity of disease, and the great number of premature deaths, which afflict our present state of being, are equally to be regarded as things immutable, and therefore to be tranquilly submitted to. But this view would be not less a mistaken one; for there is no fact more clearly ascertained, than that disease and premature death are not, and never have been, fixed at any given amount, but yield constantly to the power of any new conditions which man may be able to introduce. Regarding clear views on this subject as of great importance, we shall here enter a little into detail.

The object is, we apprehend, to shew that sickness and mortality vary both in place and in time, according to physical and organic conditions.

Inquiries into these subjects were not made in ancient times; but during the last two hundred years, such facts have been recorded as enable us to ascertain that in that space of time, with regard to nearly the whole of Europe, there has been a gradual improvement in health and life, in proportion to improved conditions. In Sweden, for instance, between 1756 and 1763, the annual mortality was, for males, 1 in $33\frac{1}{4}$; for females,

1 in 35¾; whereas in the year 1800 it had diminished to 1 in 34¾ for males, and 1 in 37½ for females. From mortuary tables preserved with considerable accuracy at Geneva, it appears that at the time of the Reformation, one-half of the children born died within the sixth year; in the seventeenth century, not until the twelfth year; in the eighteenth century, not until the twenty-seventh year; consequently, in the space of about three centuries, the probability that a child born in Geneva would arrive at maturity, has increased fivefold. In London, in the year 1606, the annual deaths were 1 in 14⅓, or 7 per cent. of the population; and in plague-years during that century it reached 25 in 100, or every fourth man, woman, and child! *In* 1838, *it was only* 1 *in* 35½. Knowing that, at the former period, the city was dense and ill-cleaned, and that the habits of the people were not then what they are now, we cannot doubt that this diminution of mortality to less than one-half is owing to the improved conditions in which human beings now live in the metropolis. Between the years 1730 and 1750, 74 of every 100 children born in London died before they were six years of age; but in more recent times, only 31 and a fraction out of every 100 die under the same age—that is to say, the deaths of children in London were then more than twice as numerous as they are now. About a century ago, the mortality of the children received into the London hospitals was of astonishing amount. Though the fact seems scarcely credible, we believe there is no good reason to doubt that, of the 2800 annually received, 2690, or *twenty-three in every twenty-four*, died before they were a year old. It was at length seen that this mortality was the effect of overcrowding, impure air, and imperfect aliment; and after an act of parliament had been procured to compel the officers to send the infants to nurse in the country, only 450 out of 2800 died in the first year. It has been ascertained that, during the last century, about a third has been added to the average expectation of life—that is to say, an individual now has as good a chance of living forty years, as he had a hundred years ago of living thirty. To what can such a fact be owing but to the diminution of the causes of disease in the improved conditions of the people?

The facts ascertained with regard to differences of mortality in different places are equally striking. A remarkable instance of the effect of marshes upon health is cited by M. Villermé. Formerly, the district of Vareggio, in Tuscany, was in this condition, and its few miserable inhabitants were every year visited by severe agues. In 1741, floodgates were erected to keep out the sea, the marsh was dried up, and ague appeared no more. Vareggio subsequently became a populous and healthy district. The Isle of Ely is a marshy district in the east of England, and it was ascertained that of 10,000 deaths which occurred in it between the years 1813 and 1830, no fewer than 4732 were of children under ten years of age; the proportion of deaths of children under ten in all the other agricultural districts of England being only 3505, or as about 3 to 4 of the former number. Of 10,000 deaths between ten years and extreme old age in the same period, there were, of persons between ten and forty, 3712 in the Isle of Ely, and only 3142 in drier districts. There are some remarkable discrepancies of mortality in different counties of England. While the proportion of annual deaths in every hundred persons under six years of age is, for the whole of England and Wales, about five and a third, the proportion in Suffolk is three and a half; in Warwick, six; in Middlesex, eight and a third. Suffolk is an agricultural county; Warwick contains Birmingham and some other large towns; and the metropolis is situated in Middlesex: can we resist concluding that the pure air and constant exercise which children obtain in the country are the immediate means of prolonging their lives; while the narrow accommodations, impure air, and limited exercise to be had in large towns have exactly the contrary effect? In the general population of England, it was a few years ago ascertained that 443 in 1000 die under ten years of age; but in Manchester and Salford the number was a third larger, or 602. Here, the miserable circumstances of many of the humbler classes in Manchester—above eighteen thousand of them, for one thing, then living *in cellars*—must be considered as the immediate cause of the disproportioned mortality. While, in 1838, the general mortality of London was, as stated, 1 annually in 35½, there were great differences with respect to different districts. In Camberwell, an open suburban district, it was 1 in 52; in Hackney, a similar district, 1 in 54; but in the huddled district of St George's, Southwark, it was 1 in 30; and in the still more dense and miserable region of Whitechapel, so much as 1 in 26, or exactly double the mortality of Camberwell.

In a late public document, we find an investigation which brings out an interesting contrast between densely and thinly peopled districts of the entire kingdom of England. 'In three districts, the annual mortality during ten years previous to 1851, was at the rate of 15 deaths in every 1000 living; in fourteen districts, at the rate of 16; in forty-seven districts, at the rate of 17 in 1000 living. Where the mortality rate was 15, 16, and 17, the average number of persons living on 100 acres was respectively 9, 17, and 22. Again, the annual mortality in the same period in thirteen districts was at the rate of 27 deaths in 1000 living; while in eighteen districts the rates ranged from 28 to 36 in 1000 living. The number of persons on 100 acres in these districts was, respectively, 279 and 693.' The connection of density of population, always attended as it is by misery, with large mortality, is thus clearly shewn.*

It is also now ascertained that England is more healthy than any continental country, the next to it in this respect being France. In continental cities, the annual rate of mortality is seldom less than 30 in 1000, and the rate frequently rises to 40 in 1000. In London, the rate of mortality in 1856 was estimated at 25 in 1000.†

Taking the whole of the above facts into account, we must see that not only do health and longevity depend expressly on laws the operation of which we can understand, but man has it in his power to modify to a great extent the circumstances in which he lives, with a view to the promotion of his organic wellbeing and preservation. We see that the draining of a marsh banishes the ague, that a change from city to country air diminishes mortality, and that the greater comforts possessed by the affluent secure them longer life than the poor. It may not immediately be in the power of every one to change his circumstances from the unhealthy to the healthy; but it is a great matter to know that the object is within human power, for then at least an encouragement is held out to induce each individual to make every possible effort to put himself, and to contribute to putting society in general, into more salubrious conditions.

The object may be said to depend partly upon individual, and partly upon social efforts. Every person has some control over the quantity and quality of the food he eats, the condition of the air he breathes, and the exercise, repose, and recreation which are demanded by his muscular and nervous system, according to the principles laid down in this and similar treatises; as also some power to refrain from injurious excesses, and to avoid the various external agencies of a detrimental kind which constantly beset him. Let him act as he ought to do in these respects, and he will reap an

* Document quoted in *Companion to Brit. Almanack* for 1857, p. 161.

† Registrar-general's Quarterly Return, 1856, No. 30.

immediate reward in that pleasurable state of consciousness which attends a healthy existence. But some of the most important requisites for health depend on public measures. The amount of the necessaries and comforts of life to be obtained by the great mass of the operative classes in all countries, depends very much upon regulations which may have been made with regard to *production* and *exchange*, as also those which may have been made for instructing and morally elevating and sustaining the bulk of the people. It unfortunately happens, in most countries, that while the bearing of certain acts upon individual happiness is fully seen and provided for, those which affect the condition of communities are imperfectly understood; so that measures destructively injurious to millions will be blindly enforced and defended by those who would severely punish the slightest wrong inflicted by one man upon another.

Measures for improving general conditions, with respect to air and exercise, are perhaps more readily practicable; yet here also the bearing of active principles upon great masses is so dimly seen, that, not to speak of more positive difficulties, it is usually long before proper sanitary regulations are made. The cleaning police of most cities is certainly improved considerably within the last fifty years; yet it is still far from being what it ought to be, while drainage continues to be extremely defective, and ventilation and means of innocent and healthful recreation can scarcely be said to be thought of. Some facts elicited by recent parliamentary inquiry, with regard to several of our principal cities, are of a most startling kind.

Dr Arnott, when examined as to the prevalence of fever in Bethnal Green, Whitechapel, Wapping, and certain other districts in the metropolis, attributed them directly to the dirty and neglected state of these localities, instancing—'Houses, courts, and alleys without privies, without covered drains, and with only open surface-gutters, so ill made, that the fluid in many cases was stagnant; large open ditches containing stagnant liquid filth; houses dirty beyond description, as if never washed or swept, and extremely crowded with inhabitants; heaps of refuse and rubbish, vegetable and animal remains, at the bottom of close courts and in corners.' [The amount of noxious matter which is allowed to collect in London is far beyond what most of its inhabitants have any conception of, as is the case with most other conditions chiefly affecting the poor.] In Manchester, 18,300 persons, or one-twelfth of the whole working population, live beneath the level of the ground, with an insufficiency of both light and air. In that town, the dwellings of labourers are often situated in narrow courts, and back to back, so as to prevent ventilation; the drains are far from sufficient; and till recently, there was not in the town one free space in which the people could enjoy the slightest recreation. In Liverpool, 39,000 persons live in cellars, dark, damp, confined, ill ventilated, and dirty. The class next above, to the number of 80,000, inhabit houses built around small courts, closely pent up, back to back, with only one entrance to each, and usually a receptacle for refuse in the centre—an arrangement which appears as if it had been expressly calculated to keep health low and mortality high. In Leeds, a similar style of building obtains, with a similar train of circumstances —'no effective drainage, inspection, or system of paving or cleansing.' The greater part of this town was described in 1839 as 'in a most filthy condition, demanding an immediate remedy.' It was mentioned, that in a certain dirty yard there was a house which for many years had been the seat of disease of a very malignant character: three years ago, the attention of the commissioners of police was directed to the extremely imperfect drainage of the surface-water: at that time, a better escape for the refuse-water was provided; and since that period, says the reporter, 'I believe *we have not had a single case of fever from that particular locality*.'

Narrow alleys and close courts, with wet filth constantly exhaling within them, and containing a densely huddled and extremely poor population, exist in Edinburgh, where, however, an exposure to high winds makes the evil less pestilential. In Glasgow, a comparatively level city, the same peculiarity exists to perhaps a greater extent than in any other British city. This, added to the miserably insufficient succour extended to the poor, and the influx of migratory Irish, renders Glasgow at present one of the unhealthiest cities in Europe; the mortality of the year 1837 being 1 in 24½, and the number of fever cases for the five years before 1839 at an average of 11,118 per annum. Here also we have a most notable instance (see No. 30, p. 473) of the counteractive power of a single sanitary principle; for a house containing about five hundred poor inhabitants, having been ventilated by a draught from each room in 1832, fever, which had previously never been absent from that dwelling, was nearly banished, only four cases occurring in the ensuing eight years, though fever raged during that period in all the other districts of the city occupied by the poorer classes.

The Larder.

FOOD—BEVERAGES.

IN the preceding sheet, we have shewn that man is destined to subsist on a mixed diet—that is, partly on vegetable and partly on animal food; and we shall now proceed to describe the specific characters of the more common alimentary substances, in as far as these have been determined by science and experience. In so doing, we shall consider their natural history and production, their chemical composition, their relative alimentary value, and the like, leaving their culinary preparation for the subject of a separate treatise. Before doing so, however, it will be necessary to establish a clear conception of the functions which food has to perform in the animal economy.

Chemical research has shewn that the food of man is composed of organic matter, water, and mineral ingredients. The mineral ingredients are required to form the skeleton or solid framework; the watery fluid is necessary to the due performance of the vital functions; whilst the organic matter supplies at once the heat and nourishment of the system. Every one knows how indispensable animal heat is to the preservation of life and health; and this heat is produced, according to the researches of Liebig and others, by the consumption of a certain portion of the food, much in the same way as fuel produces heat by being burned in our fireplaces. The elements of this portion of our food are hence termed *calorifiant*. They are also termed *respiratory*, because it is chiefly by the act of respiration that they, after having undergone various changes in the body, are brought in contact with the oxygen of the atmosphe in the lungs and capillaries (small blood-vessels) a over the body. Animal heat is thus generated by combination of the carbon and hydrogen of a portic of the food with the oxygen of the inspired air—he always being given out by such chemical changes, ar compounds of carbonic acid and water being the resul which are given off by the lungs and skin as was matter. The elements of the other portion of our foc are termed *nutritive*, because they supply the was and growth of the fabric. Every thought of the min every act of the body, changes a portion of the livir particles of our systems to dead and waste particle which, being no longer of use, are either burned by tl slow combustion already described, or carried off a excrementitious matter; and it is the province c the elements of nutrition, by going to form blood, t renew the parts where such waste has been produce The leading ingredient in the nutritive portion i nitrogen or azote; hence the terms nitrogenous c azotised are equivalent to nutritive.

From the preceding statements, it must be evider that all wholesome dietary must contain both a *hea forming* and a *flesh-forming* principle; and that, accorc ing as we live in a hot climate or cold climate, tak much exercise or remain sedentary, so must we hav recourse to food which will supply the elements whic our bodies most stand in need of. It is the province c chemistry to determine the real constituents of huma food, and to point out in what the various articl commonly used are excessive or defective; and thi

attempts have recently been made to classify substances according to their capabilities of supplying heat, flesh, and bone.

The following table gives the relative proportions of *heat-producing* and *flesh-forming* ingredients in various articles of diet:

		Flesh-Forming.	Heat-Producing.
Cow's Milk	contains, for	10	30
Human Milk	" , "	10	40
Lentils	" , "	10	21
Horsebeans	" , "	10	22
Peas	" , "	10	23
Fat Mutton	" , "	10	27
" Pork	" , "	10	30
Beef	" , "	10	17
Hare	" , "	10	2
Veal	" , "	10	1
Wheat-flour	" , "	10	46
Oatmeal	" , "	10	50
Rye-flour	" , "	10	57
Barley	" , "	10	57
Potatoes, white,	" , "	10	86
" , blue,	" , "	10	115
Rice	" , "	10	123
Buckwheat Flour	" , "	10	130

In whatever way the results may be stated, it is necessary that they be obtained with accuracy; and it is equally necessary that the condition of the body as to health or disease, rest or exercise, shelter or exposure to cold, should be also ascertained; so that, by the adoption of a proper diet, any defect may be supplied, or excess corrected. On this point, man has yet made little true scientific progress. Where he has arrived at the truth, it has been chiefly by a long process of trial and error; and it is only now that he is beginning to apply the lights of science to guide and direct him. In describing the various articles of food—vegetable and animal—we can therefore only refer to very general results: accurate and detailed experiments being yet in many instances altogether wanting. To Baron Liebig, Boussingault, Mulder, and other continental chemists; to our own countrymen, Sir Humphry Davy, Professor Johnston, Drs Thomson, Pereira, and Playfair, are we indebted for most of those researches on food which bid fair to introduce a system of dietetics, if not altogether new, at least more strictly in accordance with sound reason and economy. It must not be supposed, however, that substances which yield to the chemist the largest amount of nutritive matter, are in every case the most nutritious and wholesome. The fact is, they may contain other principles which greatly impair their digestibility, or they may be unfitted for peculiar states and conditions of health; or, what is also possible, they may be obnoxious to certain constitutions, unless administered along with the necessary correctives. Due allowance must ever be made for such exceptions; and all that we can reasonably expect of the chemist or physician, is a statement of results as applicable to healthy or normal conditions.

FOOD.

The aliment of man consists of solid and liquid substances; hence such popular distinctions as 'meats and drinks,' 'food and beverages'—the one calculated to allay the cravings of hunger, and to afford the body substantial support; the other simply to allay the sense of thirst. Such distinctions, however, are more popularly convenient than scientifically correct: milk, for example, though liquid, being the sole support of the young mammal, and affording, moreover, more substantial nourishment to every portion of the fabric than any solid substance whatever; while starch, though solid, yields little or nothing that can administer to the growth of the living tissues. Adopting, however, the common distinction of 'food and beverages,' as in some measure convenient, we shall treat the former under the three heads—*vegetable*, *animal*, and *mineral*—remarking that it is chiefly the vegetable and animal kingdoms (and especially the vegetable) from which man derives the greater portion of his solid sustenance. In the dietary of tropical countries, the vegetable element generally prevails over the animal; in temperate regions, the proportion is more equable; while in the colder latitudes, the flesh of animals may be said to be the staple of existence.

VEGETABLE FOOD.

Vegetable food, wherever employed, is consumed partly in a green and succulent state, either cooked or uncooked; partly in a ripe condition—as fruits, nuts, and the like; and partly when dried and artificially prepared—as the various bread-corns. In whatever condition or form vegetable substances may be used, they consist essentially of the same elements—carbon, hydrogen, oxygen, and nitrogen, with a small proportion of sulphur, phosphorus, and earthy salts. These are usually termed *ultimate* elements, from which the living vegetable elaborates certain *proximate* principles for the construction of its own peculiar fabric. These principles are—starch or fecula, gluten, vegetable albumen, sugar or the saccharine principle, gum or mucilage, lignin or woody fibre, vegetable jelly or pectin, fixed and volatile oils, wax, resin, balsams, gum-resins, camphor, tannin, and colouring matter. Of these, the most abundant are starch, gluten, albumen, sugar, and gum: these constitute the principal ingredients in all esculent vegetables; and it may be remarked, that starch and gluten are the most important as regards quantity—starch yielding carbon, or heat-forming, and gluten, nitrogen, or flesh-forming matter. It may also be observed, that some of these proximate principles are convertible, or nearly allied: thus starch can be converted into sugar by the processes of vitality and fermentation; and albumen hardly differs from gluten. According to the prevalence of these respective principles, writers on dietetics have proposed certain classifications of vegetable food, such as the starchy or amylaceous, the saccharine, mucilaginous, oily, and so forth. Others, again, finding that many plants yield several principles in equal abundance, and that it is impossible to draw such distinctions without leading to misconceptions, abandon this classification, and merely treat of the parts consumed, as the seeds, roots, fruits, leaves, and the like. Any rigid division of this kind is also liable to objection, since the seeds of a plant may be wholesome, while its roots are poisonous; or its leaves may be worthless, while its fruit is valuable; or it may contain a deleterious principle when raw, and yet be exceedingly wholesome and agreeable when boiled or roasted.

One of the most abundant sources of vegetable food is the cereals, or bread-corns—wheat, rye, barley, oats, millet, and maize—all of which belong to the natural order *Graminaceæ*, or grain-bearing plants. All of these grow in a similar manner; all yield starch, gluten, and a certain amount of phosphates; and all have been cultivated and improved by the inhabitants of different countries from time immemorial. They are commonly spoken of as *farinaceous* foods; their elements of *nutrition* being albumen, fibrin or gluten, and casein; and their elements of *respiration*, starch (principally), sugar, oil, and gum.

Wheat (*Triticum*), of which there are numerous varieties, justly stands at the head of the cereals. It is now grown largely in all civilised countries, and forms a principal portion of human food. The grain, freed from its bran or husk, is usually ground to a fine *flour*, and in this state is used in the manufacture of bread, pastry, macaroni, vermicelli, semolina, and other preparations. It consists, as already stated, of starch, gluten, sugar, gum, certain salts, and water; and these ingredients are

found to vary, not only with the soil in which the corn is grown, but according to the climate or latitude—that of Southern Europe yielding from two to six per cent. more gluten than that grown in the north. It is for this reason that Italian flour is so well fitted for the manufacture of macaroni; and that bakers often prefer a mixture of wheats in the composition of their loaves. The following are given as analyses of different wheats and wheat-flours:

	French Wheat.	Odessa Hard Wheat.	Odessa Soft Wheat.	First Flour.	Second Flour.
Starch, .	71·49	56·50	62·00	71·2	67·78
Gluten, . .	10·96	14·55	12·00	10·8	9·02
Sugar, .	4·72	8·48	7·56	4·8	4·80
Gum, . .	3·32	4·90	5·80	3·6	4·60
Bran, .	—	2·30	1·20	—	2·00
Water, . .	10·00	12·00	10·00	8·0	12·00

Bread is the most important article of consumption prepared from the flour of wheat, and may be fermented or unfermented.

1. Common *fermented* or *loaf-bread* consists of wheat-flour, salt, water, and either yeast or leaven (old dough already in a state of fermentation). To these, bakers occasionally add potatoes and alum—the former to assist the process of fermentation, and render the bread lighter; the latter, to augment its whiteness and firmness. As to the addition of potatoes, there can be no objection beyond the substitution of an article containing no true nutritive matter; but as to alum, it is highly objectionable, and its use by bakers is accordingly prohibited by law. The rationale of the fermenting process is this: 'The yeast or leaven causes the flour to undergo the vinous fermentation, by which carbonic acid and alcohol are formed. The carbonic acid is prevented from escaping by the tenacity of the dough, which, becoming distended with gas, swells up, and acquires a vesicular structure, forming a kind of spongy mass. In this way, therefore, are produced the vesicles or eyes, which give to ordinary loaf-bread its well-known lightness and elasticity. If the vinous fermentation be not checked in due time by *baking*, the dough becomes sour; and for this purpose, the mass, after being formed into loaves, is exposed in an oven to an elevated temperature, which puts a stop to the fermentation, expands the carbonic acid, expels the alcohol formed, and drives off all the water capable of being removed by the degree of heat employed. On weighing bread taken from the oven, it is found to be twenty-eight or thirty per cent. heavier than the flour used in its preparation.' 'In the formation of wheaten bread,' says Sir Humphry Davy, 'more than one quarter of the elements of water combine with the flour; more water is consolidated in the formation of bread from barley, and still more in that from oats; but the gluten in wheat being in much larger quantity than in other grain, seems to form a combination with the starch and water, which renders wheaten bread more digestible than other species of bread.' From pretty accurate experiments, it has been found that the proportion of nutritive to the heat-forming principle in loaf-bread is as 10 to 46; in milk, the natural food of all young mammalia, the proportion is as 10 to 40.

With regard to the other common forms of fermented bread, Dr Pereira, in his valuable Treatise on Food, has the following remarks: 'The *fine bread* prepared from flour only is the most nutritive and digestible. *Brown bread* made from wheaten meal, which contains bran, is laxative, and is used with effect by persons troubled with habitual constipation, as well as by those labouring under diabetes. *Hot rolls* are indigestible, and unfit for dyspeptics and invalids; indeed, all kinds of new bread are injurious. Rolls, both English and French, are made with a much larger proportion of yeast than is employed in ordinary bread. The different kinds of *fancy breads* are less adapted for the use of invalids, and of those who suffer from a tender stomach, than the common loaf-bread. *Compressed bread*—that is, bread which has been submitted to compression by the hydraulic press—becomes dry and hard, and may be kept for an almost indefinite period; it requires to be granulated before being used. *Rusks*, and *Tops and Bottoms*, are both made with wheat-flour, butter, sugar, and milk, and a considerable quantity of yeast to give them lightness.'

2. *Unfermented* or *unleavened bread* is prepared in two forms—either heavy and compact, or light and spongy. The former condition is that in which all the varieties of biscuits appear—the main ingredient in these being flour worked into dough with hot or cold water. *Sea-biscuits*, so largely employed in the victualling of the navy, are composed of wheaten flour and a little bran: they are hard and heavy, and are difficult of mastication. *Biscuit-powder* is not of course liable to this objection, and being prepared for use with hot water, is reckoned fair food for infants. The *captains' biscuits* of the ships are generally made of fine flour with a small proportion of butter; the so-called *Abernethy biscuits* are made variously by different bakers—most of whom add a little yeast, and flavour with caraway-seeds. In the numerous *fancy biscuits* now used, butter, milk, sugar, and the like, are indispensable ingredients; and for this reason, little definite or favourable can be asserted of their dietetic properties.

The other form of unfermented bread is that in which, by the use of effervescing compounds, it is rendered light and spongy, and made to resemble ordinary loaf-bread. Numerous receipts have been given, and several patents taken out, for the manufacture of this species of bread, but all of them may be readily comprehended from a description of the original method. It is well understood, that if we take hydrochloric acid and carbonate of soda, and mingle them in due proportions, an effervescence will take place, carbonic acid is disengaged, and common salt (chloride of sodium) is formed. Now, if we take the carbonate of soda and hydrochloric acid, and knead them as rapidly as possible with dough, an internal action will go on, the carbonic acid gas will raise the mass, the salt formed will season it, and, if properly baked, a light, sweet, and nutritious bread will be the result. Such is the rationale of all the unfermented breads now so largely in vogue; though of course various bakers have adopted various ingredients, and hit upon different modes of applying them. Wheaten flour, 7 pounds; carbonate of soda, 350 to 500 grains; water, 2¼ pints; and hydrochloric acid, 420 to 560 grains, are said to form an excellent bread. A still finer and sweeter bread is said to be prepared from the following proportions: Flour, 1 pound; supercarbonate of soda, 40 grains; cold water, half a pint, or as much as may be sufficient; hydrochloric acid, 50 drops; and powdered loaf-sugar, a tea-spoonful. According to Dr Robert Thomson of Glasgow, a good method of making unfermented bread is—to take of flour, 4 pounds; supercarbonate of soda, 320 grains; hydrochloric acid, 6 fluid drachms; common salt, 300 grains; and 35 ounces of water by measure. The soda is first mingled with the flour very intimately; the salt is dissolved in the water and added to the acid—the whole being then rapidly mixed, as in common baking. The bread may be either baked in tins or formed like cottage-loaves, and should be kept from one to two hours in the oven. Should it appear yellow, it is a proof that the soda has been in excess, and indicates the propriety of adding a little more acid—the acid varying somewhat in strength.

As to the merits of fermented and unfermented bread, the latter has the advantage in point of economy, there being no loss of nutritive principle through the destructive process of fermentation. The result of experiments upon the bread produced by the action of

hydrochloric acid upon carbonate of soda, has been that in a sack of flour there was a difference in favour of the unfermented bread of about seven loaves.

Among unfermented preparations from wheat-flour may be classed a large variety of *cakes*, *pastry*, and *pudding*. From the amount of butter, lard, eggs, fruit, seasoning, &c., which they generally contain, they form a most indigestible kind of food, totally unfit for children, invalids, and those having a tendency to dyspepsia. While these remarks apply to ordinary bakers' cakes, pastry, suet-pudding, and the like, there are certain light cakes, baked and boiled bread-puddings, which are not only agreeable, but wholesome and nutritious. The Italian preparations, *macaroni*, *vermicelli*, and *Cagliari paste*, consist of the finest wheat-flour. The first two have their well-known forms given to them by forcing the tenacious paste through a number of holes in a metallic plate; the latter is pressed into the form of stars, rings, Maltese crosses, and the like. The nutritive qualities of all these preparations, according to Pereira, are identical with wheat; and when plainly cooked, as by boiling (macaroni and vermicelli soup), they are easily digestible. *Semolina*, *manna-croup*, &c., are granular preparations of the finest wheat deprived of bran. They possess, of course, all the nutritious properties of wheat, and are very agreeable, light, and well fitted for children and invalids. The same remark applies to the so-called *farinaceous foods* of the druggist, which are either wheat, pea, or lentil flour subjected to some heating process which bursts the starch granules, or admixtures of one or other of these with that of barley or oats.

Barley (*Hordeum*), of which there are several varieties, cultivated in the British islands, is one of the cereals found all over the temperate regions of the northern hemisphere—some of the varieties coming to profitable maturity even within the limits of the polar circle. As a staple of human food in northern countries, it is used in various forms: thus, freed from their husks by milling, the grains form *pot-barley*, used for making broth; still more thoroughly freed from husky matter, and rounded and polished in the mill, they constitute *pearl-barley*, used also in broth, and sometimes boiled in water and eaten as rice with milk; the common pot-barley, ground to flour, forms the *barley-meal* of the Scotch; and from pearl-barley similarly treated is obtained the *patent barley* of the shops. In any of these forms, barley forms a wholesome and nutritious food.

The composition of barley has been stated by Einhof to be as follows:

THE RIPE SEEDS.

Meal,	70·05
Husk,	18·75
Moisture,	11·20
	100·00

THE BARLEY-MEAL.

Starch,	67·18
Fibrous matter (lignin),	7·29
Gum,	4·62
Sugar,	5·21
Gluten,	3·52
Albumen,	1·15
Phosphates of Lime and Magnesia,	0·24
Moisture,	9·37
Loss,	1·42
	100·00

In 100 parts Norfolk barley, Sir Humphry Davy found 79 starch, 6 gluten, 7 saccharine matter, and 8 husk. Proust, Vauquelin, and others have subjected this grain to analysis with very nearly the same results; and Dr Thomson adds that the gluten of barley is partially soluble in cold water, as is shewn in the steeping of the grain for malting; but it coagulates in 120° or 130°, and falls down in gray-coloured flocks. He also extracted from the husks of barley a small quantity of an oily matter, of an asparagus green colour, and taste resembling that of spirits from raw grain, to which no doubt the flavour of whisky is owing. Some persons who are habitually costive, derive advantage from the use of barley-meal cakes and porridge. We say cakes, for in consequence of the small quantity of gluten it contains, it is incapable of undergoing the panary fermentation, so as to form a light spongy loaf like flour from wheat. The barley *bannocks* or *scones* of northern countries are formed by kneading the meal thoroughly with water and a little salt, flattening the dough into cakes rather thin than otherwise, and toasting the same either on a hot iron plate (in Scotland, the *girdle*) or before a clear brisk fire. When new and properly made, bread of this kind is sweet and palatable; and though somewhat more difficult of digestion than wheaten bread, possesses the advantages already mentioned. *Barley-water*, or a decoction of pearl-barley, is reputed a soft and lubricating beverage, slightly nutritive, and very easy of digestion.

The Oat (*Avena*), of which there are also a number of varieties cultivated in Britain, is one of the hardiest of our cereals. It can be grown with advantage where neither wheat nor barley will ripen; and indeed thrives best under a cold climate like that of Scotland, if the soil on which it is planted be sufficiently dry. It cannot be cultivated in the south of Europe, and is altogether a staple for the inhabitants of high northern regions. The entire grain is largely used as food for horses; freed of the husk, it forms *groats* or *grits*, and these, when crushed, are termed *Embden groats*, and when ground to flour, *prepared groats*. In one or other of these forms, oats are pretty extensively used as human food; but more largely as *oatmeal*, which is prepared by grinding the kiln-dried groats to various degrees of fineness, according to taste. This meal is not so white as wheaten flour, and has a peculiar agreeable odour. In various districts of the country, it is used for making bread, porridge, puddings, and other preparations.

Four specimens of Scotch oats, on being carefully analysed, gave the following results:

	HOPETON OATS.			POTATO OATS.
	Northumberland.	Ayrshire.	Ayrshire.	Northumberland.
Starch,	65·24	64·80	64·79	65·60
Sugar,	4·51	2·58	2·09	0·80
Gum,	2·10	2·41	2·12	2·28
Oil,	5·44	6·97	6·41	7·38
Protein Compounds. Avenin,	15·76	16·26	17·72	16·29
Protein Compounds. Albumen,	0·46	1·29	1·76	2·17
Protein Compounds. Gluten,	2·47	1·46	1·33	1·45
Epidermis,	1·18	2·39	2·84	2·28
Alkaline Salts and loss,	2·84	1·84	0·94	1·75
	100·00	100·00	100·00	100·00

From these data it would appear that oats are superior in point of nutrition to wheat; and experience proves that they form a substantial nutritive article of diet, since many of the labouring classes in Scotland, in Lancashire, Derbyshire, Northumberland, and other parts of England and Wales, subsist chiefly upon bread, pottage, and other oaten preparations. Oaten food, according to Pereira, is apt to disagree with those having a tendency to dyspepsia: in other words, it is apt to become acid on the stomach, and oat-bread, in particular, to occasion heartburn. With good digestive organs, however, and a proper amount of vigorous exercise, no inconveniences of the kind are experienced. *Porridge* or *stirabout*, which is composed of oatmeal, water, and a little salt, when well boiled, is one of the best forms in which oaten food can be taken, and partaken of with milk, constitutes a capital breakfast

Gruel is a mild, nutritious, and, in most cases, an easily digested article of food. On account of the nitrogenous principle which it contains, it is of course more nourishing than the starchy preparations (arrow-root, sago, tapioca, &c.) frequently employed in the sick-chamber. It may be prepared either from oatmeal or ground groats (Robinson's, for example), and may be sweetened with sugar, acidulated with lemon-juice, or spiced. Butter should never be added in the case of the dyspeptic, or where the stomach is tender. *Oaten-cake*, unless made with scalding water, and well fired, is apt to be heavy and heating.

Rye (*Secale cereale*), though cultivated to some extent on the light sandy soils of our country, can scarcely be considered as one of the staples of British consumption. The small amount grown, however, generally meets with a ready market, partly for distillation, and partly for the making of a light spongy bread, having a peculiar but rather agreeable flavour.

The composition of rye has been ascertained by Einhof and Boussingault, with the following results:

RYE-SEEDS.

	Einhof.	Boussingault.
Husk or bran,	24·2	24
Pure meal,	65·6	63·08
Moisture,	10·2	12·92
	100·	100·00

RYE-MEAL.

	Einhof.	Boussingault.
Starch,	61·07	64·0
Gum,	11·09	11·0
Gluten,	9·48	10·5
Albumen,	3·28	
Saccharine matter,	3·28	3·0
Husk,	6·38 & salts,	6·0
Undetermined acid and loss,	5·42	2·0
Fatty matter,	0·00	3·5
	100·00	100·

'The husk,' says Webster, in his *Cyclopædia of Domestic Economy*, 'possesses an aromatic and slightly acidulous flavour, which renders it agreeable to the palate. The bran should not, therefore, be entirely separated from the flour; for if the grain be ground fine, and divested entirely of the husk, the bread will be deprived of much of its pleasant taste. Rye-bread is consequently made of coarse flour, which, together with its dark colour, has probably given rise to much of the dislike to it in this country. The quantity of gluten which it contains accounts for the facility with which it may be fermented into spongy bread, which is not the case with oats and some other grains. But bread made of it very soon becomes sour, indeed it undergoes an acetous fermentation in the process of baking, and is thought to have a gentle action on the bowels. In some farmers' families, household bread is made of a mixture of one-third rye and two-thirds wheaten flour, which makes a sweeter bread than that solely of wheat, and is preferred to any other by those who are in the habit of using it. The bread is very firm and solid, and retains its juiciness and moisture long, being also very nutritious.' Though little used with us, rye-bread, under the title of black-bread, is largely consumed by the peasantry of Sweden, Germany, Russia, and other northern countries, and has proved itself a very nutritive and strength-producing article of diet.

Rice—the *Oryza sativa* of botanists—is a plant of Asiatic origin, but is now extensively cultivated not only in China, India, and other eastern countries, but in the West Indies and the southern states of America, as well as in the rich alluvial lands of Lombardy and in the province of Valencia in Spain. 'It is the grand material of food,' says Marsden, 'on which a hundred millions of the inhabitants of the earth subsist; and, although chiefly confined by nature to the regions included between and bordering on the tropics, its cultivation is probably more extensive than that of wheat, which the Europeans are wont to consider as the universal staff of life.' Requiring a warm climate, it cannot be grown in Britain; but we import it largely—the Carolina and Patna rice being the most esteemed in the market. It is brought chiefly in the shelled or cleaned state; though attempts have been made to import the *paddy*—that is, rice in the husk—with a view to obtaining the grains in a fresher condition.

Rice consists chiefly of farina or starch, 100 pounds from Carolina yielding, according to Braconnot, not less than 85 starch, 5 fibrous matter, 4 glutinous matter, and 5 water, the remainder being sugar, gum, and phosphate of lime. It is therefore evidently much less nutritious than any of the preceding cereals, though it is light and wholesome, and altogether a valuable food when taken along with milk or some corrective condiment. It is prepared as an article of food in various ways, either whole or ground. It may be used like barley in broth, boiled and eaten with milk, boiled and dried as a substitute for potatoes, as an accompaniment to curried dishes, or baked in puddings, which is perhaps the best mode of using it. What are called *rice-cakes* consist of about one-third of their weight of ground-rice, the rest being flour, eggs, and sugar. *Rice-water*, employed like barley-water as a demulcent, or soothing application, is obtained by boiling well-washed rice in water. Though, on the whole, light and digestible, rice possesses a constipating quality, which somewhat detracts from its value as an article of habitual use.

Maize or *Indian Corn* is the produce of the *Zea mays* of Linnæus—a cereal found native in America, but now largely cultivated, not only in the New World, but in several of the warmer regions of the Old. As an article of human subsistence, it is extensively used in the countries where it is grown; but did not, till the recent failures of the potato-crop, meet with much attention in Britain. In America, the tender young ears, in their milky state, are roasted and eaten with butter and salt as a delicacy, or boiled with meat. When green, they are also pickled as gherkins (young cucumbers); and dried, they keep all the year. When the grains are ripe, the skin is taken off, and the farinaceous part is boiled whole, or ground into meal, and made into cakes, puddings, &c. It is this meal which is chiefly known in Britain, and of which a variety of puddings, cakes, and loaves have been recommended.

Being extremely productive, maize can in general be cheaply procured; hence its importance in years when the staple of our own country fails. We find that those who live chiefly upon maize are robust, healthy, and fond of it as an article of diet. It is somewhat laxative, and requires to be taken with caution till the system becomes habituated to its use. To make good palatable *maize-bread*, Dr R. Thomson recommends the grains to be reduced to a fine meal, and then mixed with one-third its weight of best flour, and fermented. When thus prepared, the bread is dark coloured, and cannot be made much lighter than coarse wheaten bread. The shade, however, is of a peculiar yellow, not to be mistaken for that of wheat, besides that the taste is altogether different.

Peas and *Beans*, which belong to the leguminous order of plants, are consumed partly in a green state, and partly when ripe and dried. It is the latter state with which we have at present to do; and it may be stated generally, that their meal or farina is now but little used as an article of human food. Peas, split or whole, are used in the preparation of pea-soup; the meal, either pure or mixed, is still employed in some districts in the making of cakes; and, very finely ground and bolted, it is used as a supper-diet, under the name of *Glasgow brose-meal*. With regard to the amount of nitrogenous or nutritive matter which pulse and lentils

contain, it is beyond what is found in any of the cereals. The nutritive effect, however, does not agree with this theoretical conclusion, partly from their deficiency in other wholesome constituents, and partly from the difficulty with which they are digested, and the flatulence and costiveness they occasion, as well as from the acridity they are said to communicate to the blood.

Sago—Tapioca—Arrow-root.—Of a considerable number of foreign starchy products, these are the most extensively used, and best known in Britain. The first is the produce of the sago-palm (*Sagus rumphii*), a native of the East Indies and Indian Archipelago. 'The part which affords the sago is the pith; and to procure this, the body of the tree, when it is full grown, is sawn into pieces, and the raw sago cut out and put into a trough with water, in which it is well stirred, to separate the flour from the woody fibre. This is now suffered to rest, and the flour subsides to the bottom. The water is then poured off, and the meal laid upon wicker-frames to dry. To form it into the round grains in which it is imported, the sago, when moist, is passed through a cullender, and rubbed into little balls, like shot, and then thoroughly dried. The sago-tree requires to be seven years old before being fit for felling; and a full-grown specimen will yield about 600 pounds of sago. The best sago is of a slightly pinkish hue, and readily dissolves to a jelly in hot water. Several other trees besides that above mentioned yield sago, but neither so abundantly nor of so excellent a quality.' The sago of commerce is imported either as sago-meal, pearl-sago, or common brown sago, which states have reference more to its form than composition. In all, the main constituent is starch, which, being light and easily digestible, renders sago an eligible substance for the dyspeptic and invalid. *Sago-puddings* (made like tapioca) are by no means uncommon; but the common mode of use is *sago-milk*. This is prepared by soaking the sago in cold water for an hour, pouring off this water, and then either boiling slowly in milk, or in a little water to which milk is afterwards added. This mixture may be taken plain, or sweetened and seasoned to taste.

Tapioca is obtained from the tuberous root of the *Janipha manihot* by grating and washing. It is usually met with in small irregular lumps, a form it has acquired by being dried on hot plates. The heat breaks the starch globules, and renders them partially soluble in cold water. In boiling water, tapioca becomes a transparent and viscous jelly. 'In its nutritive qualities,' says Pereira, 'it agrees with sago, than which it is much purer, being free from colouring matter. It also yields a more consistent jelly than some other kinds of starch. It is principally employed as an agreeable light nourishment for invalids, as well as for children.' Tapioca-milk is made in the same way as sago-milk; but tapioca being more soluble than sago, requires only half the time for its preparation.

The pure white starchy powder known as arrow-root, is obtained from the tubers of the West Indian plant, *Maranta arundinacea*. It makes a tolerably strong jelly, stronger than that of wheat-starch, and is free from colouring matter, and also from any unpleasant taste or odour. It is used either in the preparation of puddings, gruel, or milk, like sago and tapioca. 'The best arrow-root we have,' says Webster, 'is from Antigua, Jamaica, and Bermuda; but a great deal of what is sold in London is adulterated with potato-starch, which, though a substance not very different, has not precisely the same properties. Arrow-root, like every kind of starch, boils to a jelly; but it differs from potato-starch in this respect, that the jelly formed from arrow-root will remain firm for three or four days without turning thin or sour, whereas the jelly from potato-flour, in the course of ten or twelve hours, becomes thin as milk and acescent; hence it is not so well calculated for food, and particularly infants'.' The proper value of all these substances, however, is now much better known; they contain but a small portion of gluten in proportion to the starch; and as starch can only supply heat-forming matter, they are less fitted for the purposes of nutrition. As food for the young, they are by far too largely employed; and the best American wheat-flour, good Scotch oatmeal, and barley-meal, may all be employed with advantage at different times, by way of variety, and repeated according to their agreement with the child's organs of digestion. The digestion of all these forms of food containing starch is greatly promoted by long boiling either with water or milk, as this process is just so much saved to the intestinal organs. It is thus obvious that we have a great variety of food fitted for children, of which we know the composition, and that we should prefer it to any species of compounded stuff of the constitution of which we are ignorant.

The Potato (*Solanum tuberosum*) is one of our most abundant amylaceous or starchy vegetables, and next to the cereals, is one of the most common articles of human food. Originally discovered in South America, it is now introduced into almost every quarter of the globe, where it seems to thrive, and to break into innumerable varieties, differing in shape, size, colour, flavour, and quality. Without noticing minutely the peculiarities of the numerous varieties, we may remark that those of middling size, and which become white, mealy, and void of any especial flavour when boiled, are in general the most esteemed, as they are the most wholesome and nutritious. As they are an easily raised crop, producing twice as much bulk of food from the same extent of land as wheat, potatoes are very largely grown in the British Islands, and, notwithstanding the recent failures, are likely still to be so. The disease to which we allude having drawn much attention both to their natural history and economical importance, there is perhaps no object of culture or article of diet which has elicited so many and contradictory opinions. Some would apparently have the potato altogether eradicated from our soil; others, taking a more modified view, would 'never allow it under any circumstances to occupy, as the staple aliment of any class of our population, the place of the grain-bearing plants;' while a third party see in it 'a cheap and available source of subsistence to the poor, which has had, in addition, much effect in lessening the prevalence of scorbutic, calculous, and arthritic disorders.' Without pronouncing dogmatically on the subject, we shall merely present the leading dietetic properties of the potato, as set down by Liebig, Pereira, and Webster. The most correct opinion respecting the nutritive properties of potatoes will be obtained from the consideration of their constituent principles. They have been analysed by various chemists. The analysis of Einhof, which is generally considered the best, is in 100 parts:

Water,	72·6
Starch,	15
Fibrous Matter,	7
Albumen,	1·4
Mucilage,	4
	100·

Like all the *Solanaceæ*, or Nightshade family, the potato contains a poisonous principle (solanine); but this is wholly destroyed by cooking. Citric and tartaric acids are also said to be present in various parts of the growing plant, and to these are likely to be ascribed the reputed antiscorbutic properties of the tuber. The fibrous matter in Einhof's analysis appears to be a peculiar modification of starch, which, as well as that substance, may be employed for food; but it is to be noticed that there is no gluten, unless the albumen be considered as nearly the same thing. According to Johnston's *Chemistry of Common Life*, the potato contains 75 per cent. of water, and 25 of dry food. Of 100 parts of this dry food, again, 92 parts are starch and 8 parts are gluten, or a corresponding principle. Potato-meal is thus remarkably similar to rice-meal. No doubt can

be entertained of the wholesome nature of the potato, when we consider the numerous hardy peasantry of Ireland, many of whom subsist almost entirely upon this useful vegetable. It must not, however, be imagined that potatoes contain the same nutritive powers as bread, weight for weight. It has been estimated, as the result of experiments made by Percy and Vauquelin, that one pound of good bread is equal to two and a half or three pounds of potatoes, and that seventy-five pounds of bread and thirty of meat are equal to three hundred pounds of potatoes.

In Britain, potatoes are generally brought to table boiled plain; but in France they are cooked in a great variety of ways, and furnish very agreeable dishes. *Potato-soup* (see PREPARATION OF FOOD) is a very palatable and thrifty mode of cooking; and *mashing* them with various ingredients, though it produces a more savoury dish, does not certainly contribute to their digestibility. It is of little signification, as affecting the digestibility, whether the potato be roasted, or baked, or boiled, provided the quality and the cookery be unimpeachable. The new or immature potato is much less easily digested than the fully ripened tuber, and should certainly be forbidden to the majority of dyspeptics. Early and forced potatoes must be less easily digested than those which have been grown with the advantages of free exposure to the air and the sunshine. As already stated, potatoes are used in the manufacture of loaf-bread; and *potato-starch*, which is nothing more than dry starch-powder, is used not only in fine bread and pastry, but as a substitute and adulterant of arrow-root. *Bright's nutritious farina* is said to be a carefully prepared potato-starch, slightly scented; and we believe several of the 'farinaceous foods' of the shops are of similar origin. The most that can be said of them is, that they are sufficiently light, and not unwholesome, but by no means nutritious.

The *Cabbage tribe* (*Brassica*)—which includes the common white and red cabbages, the savoy, greens, cauliflower, broccoli, &c.—is pretty extensively cultivated in Britain (see KITCHEN-GARDEN) for the purposes of human food. The parts used are the leaves which *heart* or gather together; and in the case of the cauliflower and broccoli, it is the young and compact flowering heads. As nutritive products, they rank high theoretically; but as they contain upwards of 90 per cent. water, a larger quantity requires to be consumed for the purposes of nutrition than would be either wholesome or agreeable. For healthy constitutions, they supply a valuable mixture with animal food; but for the dyspeptic, they are apt to prove indigestible, and productive of flatulency.

The Turnip (*Brassica rapa*), which belongs to the same family, is perhaps still more largely consumed. The varieties best adapted for human food are the Swedish, yellow, and Dutch, all of which contain a considerable quantity of sugar and mucilage, with but little gluten. A hundred parts of turnip-bulb yielded Boussingault 92·5 water, and 7·5 solid matter; and this, when dried, only 1·7 of nitrogen—being but a third of the amount found in dried cabbage. Sir Humphry Davy estimates the nutritious matter of turnips at about 4 per cent.; but though thus slightly nutritive, they form an excellent culinary vegetable, and are either eaten alone, mashed, or cooked in soups or stews. Pereira regards them as of easy digestion, and has never seen them produce flatulence when well boiled. Turnip-tops, or the young leaves gathered in spring, are occasionally used in England as greens, but are very apt to disorder the bowels.

The Carrot and *Parsnip* are two well-known umbelliferous roots, possessing highly nutritive properties, if chemical composition is to be taken as the test of alimentary value. They contain vegetable fibrin, albumen, sugar, and a volatile oil; 1000 parts yielding 95 sugar and 3 starch, or about six times the amount of sugar found in potatoes. They are valuable culinary vegetables in soups and stews, and ought to be much more largely used. The fibrous matter they contain renders them somewhat difficult of digestion if not well boiled—a matter admitting of very easy remedy.

Beet-root, though largely made use of on the continent, is chiefly employed in England as a garnish for salads and other dishes, and as pickle. According to the experiments of M. Achard, 14 pounds of beet yield 1 pound of sugar; hence the manufacture of sugar from this root, and also its value in a culinary point of view. During the recent potato-failures, various preparations of beet were recommended as food for the poor; and among others, *beet-bread* from an admixture of finely rasped beet and wheaten flour, fermented and baked in the usual form. 'We have had the experiment tried,' says Dr Lindley, 'by rasping down a red beet-root, and mixing with it an equal quantity of flour; and we find that the dough rises well, and forms a loaf very similar to good brown bread in taste and appearance. We regard this as an important discovery, because no crop is so readily cultivated, or will yield so large a return as beet, and likewise because of its great value in point of nutrition.' We may add, that either the red beet, the white sugar-beet, or the carrot, may be used with success in this manner.

Of the vast variety of garden vegetables used as salads, pickles, garnishes, and so forth, none are consumed in such abundance as to entitle them to especial notice. Many of them are no doubt useful, others are useless, and not a few positively hurtful, though fashion and caprice may give them a place on our tables. Some notice of the more prominent—as lettuce, radish, spinach, celery, asparagus, artichoke, parsley, cress, onion, and the like—will be found under KITCHEN-GARDEN and COOKERY.

Sugar.—As already mentioned, sugar exists both in vegetable and animal substances, but more abundantly in the former. In many of the products already noticed, the saccharine principle forms no unimportant item, though not in such proportion as to be considered characteristic. We now come to consider it as a distinct principle, and as an article of vast dietetic importance. Sugar, as a vegetable product, is found in considerable quantity in such dried fruits as the currant, raisin, fig, date, tamarind, and so forth; and these are now pretty largely consumed in Britain. Thus, figs yield about 60 per cent. of sugar; tamarinds, 12; prunes, 16; and dates, 35; and there can be no doubt that these, as well as many of our ripe fleshy fruits, owe their chief alimentary value to its presence. It is, however, as a separate and prepared article that we have now to do with it—as a substance obtained by art from the sugar-cane, the maple, the beet, the palm, and other plants yielding it in abundance. Though procured from the maple in America, from the beet on the continent, and from the palm in the East Indies, it is solely from the sugar-cane of the tropics that Britain obtains her supply, amounting annually to nearly 7,000,000 hundredweights. When the canes, of which there are several varieties, have attained a certain height and age—about twelve or thirteen months—the cuticle having become smooth, dry, and brittle, they are cut, stripped of their leaves, and crushed between rollers to express the juice, which is mixed with lime to neutralise the free acid present, and render more liquid and separable the uncrystallisable portion, known as molasses or treacle. The juice is now heated to the temperature of 140°, and separated from the scum, and again heated several times, and at length allowed to drain, for the separation of the *molasses* and the crystallisation of the sugar. The *raw* or *brown sugar* thus formed is again purified, by being acted upon by lime and bullock's blood: the one serving to neutralise the acidity of the liquids; the other, by the coagulation of the albumen, effecting the clarification and mechanical separation of any foreign insoluble matters. Reduced

to a certain sirupy consistence, the sugar is poured into moulds, and agitated for a certain time, to prevent the formation of large crystals, and secure a compact mass of closely adherent, small, and glistening grains. This constitutes *loaf-sugar*, the quality of which depends greatly on the lowness of the temperature at which the boiling has been effected. When sugar thus refined has been again dissolved, and left to crystallise slowly at a somewhat elevated temperature, in boxes crossed with threads, to form centres of crystallisation, *sugar-candy* is formed; or if sugar so dissolved is made to cool more quickly, a transparent solid is obtained, known as *barley-sugar*. Sugar in one or other of these states constitutes the basis of almost all *confectionary*, as acidulated drops (sugar and tartaric acid), toffy, hardbake, comfits, lozenges, and the like. It forms also an excellent antiseptic, and for this purpose is used as a *sirup* for preserving fruits, roots, &c., as well as for the curing of meat and fishes.

In whatever form sugar or the saccharine principle may be made to appear in commerce or in diet, its ultimate composition, when pure, is carbon, oxygen, and hydrogen; or more simply, carbon and the elements of water. It contains no azotised principle, and thus its function in the animal economy is to supply heat and not nutrition. 'The fondness of children for saccharine substances'—we quote Pereira—'may be regarded as a natural instinct; since nature, by placing it in milk (woman's milk contains upwards of 6 per cent. sugar), evidently intended it to form part of their nourishment during the first period of their existence. Instead, therefore, of repressing this appetite for sugar, it ought rather to be gratified in moderation. The popular notion of its having a tendency to injure the teeth is totally unfounded; Dr Wright informs us that no people on the earth have finer teeth than the negroes of Jamaica. Sugar is readily digested by the healthy stomach; though in some dyspeptic individuals it is apt to give rise to flatulency and preternatural acidity of the stomach. In some diseases—as diabetes, for example—it should be altogether excluded from the diet.' Contrary to this opinion as to the digestibility of sugar, Dr Robertson pronounces pure sugar to be 'by no means easily digested,' and that it only becomes so when sufficiently mixed and diluted with other juices. Molasses, on the other hand, from containing more component water, is more easily digested, at the same time that it is usually laxative in its effects. It is still, nevertheless, saccharine matter, and is still apt to irritate the digestive organs, and thus to interfere with and derange the processes of ultimate assimilation.

Honey, though, strictly speaking, obtained through the medium of the animal kingdom, may with little impropriety be considered in this place. It is but a weaker form of sugar, and although elaborated by the bee, is still found ready-made, if we may so speak, in the flowering apparatus of many plants. It consists chiefly of grape-sugar, containing a greater or less amount of cane-sugar. Besides these two sugars, honey also contains a free acid matter not yet well understood, mucilage, sometimes a little wax, together with colouring and aromatic matter. These adjuncts differ, according to the kind of flowers on which the bees feed; and occasionally honey has been known to possess narcotic and poisonous properties. Its dietetic properties are thus spoken of:—Like treacle, honey often acts as a laxative, and to a greater degree. But, like all other concentrated forms of saccharine matter, the digestibility of honey is only a comparative question; and, although honey may be much less apt to derange the functions of assimilation than cane-sugar or treacle, it is nevertheless by no means easily digested when the stomach is either weakened or otherwise less equal to its duties; and should always be used cautiously by the dyspeptic, if used at all by them. With some constitutions, it by no means agrees, and has to be carefully avoided.

The fleshy fruits, as the apple, pear, plum, peach, and the like, though generally consumed during their seasons, cannot be regarded as a staple of food, though they are all more or less nutritious. About 80 parts in 100 are water, the rest consists of sugar and peculiar acids, associated with more or less gluten. According to Johnston, the perfectly dry gooseberry is about as nutritive as ordinary wheaten flour. Some, as the pear and apple, are employed in the manufacture of BEVERAGES; and as to their acid properties, these will be considered under the principles of MEDICINE.

ANIMAL FOOD.

Animal, like vegetable substances, are resolvable into ultimate and proximate principles. The *ultimate elements* of 100 parts ox-blood, for example, are—51·95 carbon, 7·17 hydrogen, 21·39 oxygen, 15·07 nitrogen, and 4·42 insoluble mineral matter. Again, 100 parts beef yield 52·59 carbon, 7·89 hydrogen, 19· oxygen, 15·22 nitrogen, and 3·30 insoluble ingredients. Comparing this with what has been said of vegetables, the vast preponderance of nitrogenous or nutritive matter will be readily perceived. The *proximate principles* of animal food are—fibrin, or the fleshy fibre of meat when boiled to rags; gelatine, or animal jelly; albumen, or white of eggs; oil and fat; osmazome, which gives to meat its peculiar flavour; kreatine, a peculiar crystallisable juice; caseine, such as the curd of milk or cheese, which is nearly allied to albumen; and, we may add, sugar, as in the case of milk. Of these principles are all animal bodies composed; always bearing in mind the large percentage of water which they contain. These principles vary considerably in ultimate composition—thus, 100 parts of fibrin yield 53·36 carbon, 7·03 hydrogen, 19·68 oxygen, and 19·93 nitrogen; while albumen yields 50·00 carbon, 7·78 hydrogen, 26·67 oxygen, and only 15·55 nitrogen. Of course their relative values in point of nutrition depend upon the ultimate constitution; and this must be obtained with accuracy before any comparison can be instituted between fibrin and gelatine, gelatine and albumen, or albumen and caseine.

In treating of animal food, some writers attempt to classify it according as it may be derived from the flesh, blood, viscera, bones, cartilages, ligaments, cellular tissue, milk, &c. As our limits, however, prevent any such minute consideration, we shall merely remark, that all these portions of the animal body are less or more prized and made use of; and that they differ in nutritiousness, not only according to the kind or species of the animal, but according to the age, sex, food, and mode of life of the individual. Thus the flesh of young animals is more tender than that of old; that of the entire male adult, coarser and tougher than that of the female. Again, feeding and exercise are not without their influence; and just as the fibres of flesh are loose, tender, and minute, so are they the more easy of digestion. With these preliminary remarks, we shall proceed to notice in detail the leading articles of animal food made use of in Britain.

Beef, or the flesh of the full-grown ox, is largely consumed in Britain, perhaps more largely than a due regard to health and economy would allow. The quality of this article depends upon a variety of circumstances, such as the breed, sex, and age of the animal, and likewise the kind of food with which it has been supplied. 'Bull-beef,' says a leading authority on *cuisine*, 'has a strong disagreeable flavour, and is dry, tough, and difficult of solution. The flesh of the *ox* is more soluble; the fat is better mixed, the meat more sapid, and highly nourishing and digestible, if the animal is not too old. The flesh of the *cow* is sufficiently fit for nourishment, but is inferior to ox-beef; *heifer*-beef, or that of the young cow, is much esteemed; but that of an old fatted cow is bad. The beef of the larger varieties of the ox is inferior to that of the smaller breeds; the

former is in perfection from five to seven years old; the latter may be taken a year or two sooner. Grass-fed beef, or that produced from good farm-produce, is always better flavoured and more digestible than that reared from oil-cake, brewers' wash, and the like.' Beef is consumed both in a fresh and salted state; it is also pickled, smoked, and otherwise prepared. Salted, it is more difficult of digestion, while the salt, moreover, destroys a considerable portion of its albumen. Preserving it fresh in hermetically sealed vessels, from which the air has been expelled, is now extensively adopted, with the best results. For various modes of pickling and preserving, as well as for an estimate of the comparative merits of boiling, broiling, and roasting, the reader is referred to the following article on the PREPARATION OF FOOD.

Veal, or the flesh of the calf, is tender and nourishing, but not so easy of digestion as the prime parts of beef and mutton. Veal, particularly if it be young, contains much gelatine, as is the case with all young animals, and therefore yields a great deal of soluble matter when boiled long in water. This fact has led to the idea of its being more nourishing than meat which is less soluble; but this does not follow, for the gastric juice acts differently from water, and can digest what that fluid cannot. Veal contains more nitrogenised matter than beef.

Besides beef and veal, strictly so called, the intestines, heart, lungs, bones, marrow, cartilage, &c., of the ox are variously made use of; none of them, however, possessing the same amount of nutritious matter as the true flesh, nor being so digestible and wholesome. 'Animal flesh being identical with our own flesh and blood, say chemists, it requires neither addition nor subtraction to render it nourishing;' but in order that it may reach the different organs, it is necessary that it should be reduced to a liquid form (blood).

Mutton, or the flesh of the full-grown sheep, is also extensively consumed in Britain, and that almost wholly in a fresh state. Compared with beef, it is lighter, and more easily digested, owing very probably to the greater fineness of the fibres. 'The quality of mutton,' says the authority already quoted, 'varies much in the different breeds. In the large long-haired sheep, it is coarse-grained, but disposed to be fat. In the smaller and short-woolled breed, the flesh is closest grained and highest flavoured; but the quality is probably most affected by the food on which the flocks are fed. Those which range over the mountainous districts of Wales and Scotland, or the chalk-downs of England, and feed upon the wild herbage, possess a flavour very superior to those kept on rich pastures and marsh-land. Marsh-fed mutton often becomes extremely fat, but the meat has a rank taste. Turnips, hay, chaff, bran, corn, and other vegetables, as likewise oil-cake and grains, are employed for fattening sheep; but such mutton is never so good as that produced where the animals range at freedom. *Tup*-mutton, or the flesh of the ram, has a strong disagreeable flavour, and is usually tough; ewe-mutton, if under two years old, is good, but after that, it becomes hard and tough; wedder-mutton is the most esteemed. Mutton is in perfection at five years old, being then sapid, full-flavoured, and firm, without being tough; and the fat has become hard. Mutton under three years old is deficient in flavour, and is of a pale colour. *Lamb*, as the flesh of the young sheep is termed, is more tender and less exciting than mutton, but is not readily digested. It receives the name of lamb from the time it comes into season, in April or May, till the ensuing Christmas.

Pork, or the flesh of the pig, is invariably set down by writers on dietetics as difficult of digestion, but less so when pickled and cured than when fresh. Those who pursue the occupation of curing, cut the carcass in pieces, and pack it in kits formed to hold from one to two hundred pounds' weight. A brine is then made by dissolving salt in water, until the mixture is so thick that an egg will swim in it. This is boiled, and poured upon the pork after it has cooled. Russian pork, always much esteemed, is steeped in a brine containing 2 pounds of loaf-sugar and 3 ounces of saltpetre, to 6 pounds of salt, the whole being boiled in 6 gallons of water. After brine is added to pork in kits, the end of the receptacle is fixed in, and the article is usually sufficiently cured in a few days.

Hams are the cured hind-legs of the pig, and are considered the finest parts of the animal. They are generally in great request, and form an article of extensive consumption in Britain. The following are general directions for curing them: In the first place, the legs require to be cut in a neat rounded form, and it is usual to prepare a number at a time. Being properly prepared, pack them with rock-salt in a suitable tub or cask, being careful not to lay the flat sides of the large pieces upon each other, and filling the intervals with hocks, jowls, &c. To every 300 pounds of meat, take 20 pounds of rock-salt, or Onondago coarse salt, 1 pound of saltpetre, and 14 pounds of brown sugar, or half a gallon of good molasses, and as much water (pure spring-water is the best) as will cover the meat; put the whole in a clean vessel; boil and scum; then set it aside to cool, and pour it on the meat till the whole is covered some three or four inches. Hams weighing from 12 to 15 pounds must lie in the pickle about five weeks; from 15 to 25 pounds, six weeks; from 25 to 45 pounds, seven weeks. On taking them out, soak them in cold water two or three hours, to remove the surface-salt; then wipe and dry them. It is a good plan, in cutting up, to take off feet and hocks with a saw instead of an axe, as it leaves a smooth surface, and no fractures for the lodgment of the fly. Some make only six pieces of a trimmed hog for salting, but it is more convenient, when intended for domestic use, to have the side-pork, as it is called, cut in small pieces. The goodness of hams and shoulders, and their preservation, depend greatly on their smoking, as well as salting. The requisites of a smoke-house are, that it should be perfectly dry; not warmed by the fire that makes the smoke; so far from the fire, that any vapour thrown off in the smoke may be condensed before reaching the meat; so close as to exclude all flies, mice, &c., and yet capable of ventilation.

Bacon is the whole side of a pig cured. The method of preparation is as follows: After being killed, the carcass should not be scalded to remove the bristles, as in the case of pork, but singed off by being covered lightly with straw, to which fire is applied. When the burning straw has cleared one side, the other side may be cleared in the like manner. By this means all the hair is to be singed clean off, but without scorching the flesh, and then the skin is to be well scraped as a finish. This singeing process gives a fine firmness to the bacon, which scalded bacon never possesses.

Bacon has been much vaunted by some as a remedy for indigestion, while by others a totally different opinion is entertained. 'In the large majority of cases,' says Dr Robertson, 'it cannot be so; but, on the contrary, must tax still further the powers of the stomach, or irritate still further its tissues, which under such circumstances may be already in a state of morbid sensitiveness. Bacon is obtained from the most difficultly digested of the meats, the fleshy fibres of which are toughened by the salt and by the drying. That fat is rendered more digestible by being impregnated with salt, is an admitted fact; and this must of course qualify these strictures on the use of bacon. But the lean of bacon is rendered more difficult of digestion by the same process that has increased the digestibility of the fat; and the fat is not by any means so altered in character, as no longer to irritate the debilitated stomach. I have no hesitation in saying, that

in the greater number of cases of dyspepsia, bacon does harm.'

Brawn.—Boars are also fattened for the purpose of procuring an article of food under this name. Male pigs of all ages are put into feeding with this view, but those experienced in such matters prefer them of the age of two years. They are kept separately, in pens which will not permit of their turning round, perfect inactivity being held to conduce to their fattening. Their food is beans, with water, into which a small quantity of sulphur has been put. The collar of the animal is the part prepared for brawn, by the processes of pickling and drying. A large collar will weigh about thirty pounds, and is valued at about £3 in the market.

Lard is that part of the fat of the pig which melts easily, and forms a fine, soft, white grease. It is extensively used not only in household economy, but by the pastry-cook, apothecary, and perfumer. It should be, according to Martin Doyle, of *two* qualities: the finest and whitest—that taken from the sides—should be chopped into small pieces in a pan, over a slow fire, and kept constantly stirred, lest it should stick to the sides of the boiler; then strained, and put into bladders. The bladders should be turned inside out, and thoroughly purified by having all the fat cut out, and be well blown and dried in the open air. Lard of the first quality, when well made, is far better than any salt butter for cookery, and, from the delicacy of its colour, is used by confectioners for the finest kinds of cake and pastry. The inferior lard is obtained from the intestines, and is treated as the finer lard in every particular. The *blood* of the pig, we may also observe, furnishes a distinct article of food—being used in the preparation of the black-puddings of the shops.

Venison—Hare—Rabbit.—The flesh of the deer, hare, rabbit, and other game found in the British Islands, can never be considered as an article of general consumption. The comparative scarcity of these animals, and the fact that they are in season or fit for food only during the colder months of the year, when they become objects of fashionable capture, render them rather luxuries for the middle and higher classes, than a staple of food for the bulk of the population. The ultimate analysis of their flesh is much the same as that of the domestic animals, differing, however, in proximate character, and also in containing certain flavouring principles of a bitter or acid nature. From their constant motion and exercise, wild animals acquire a drier and harder flesh than that of the tame; and those parts which have the least motion—as the back of a hare, for example—are most juicy and palatable. From the same cause, the fluids of these animals are more heating, and much more apt to putrefy than the fluids of the domestic kinds.

The term *venison*, though applicable to the flesh of all animals which are caught by way of hunting, is generally restricted to that of the deer kind—as the buck, the doe, the hart, and the hind. When well fed, killed at the right season, and properly dressed, venison forms a palatable as well as a wholesome and readily digested food. To the injury of health, however, it is generally eaten when half-putrefied, notwithstanding its natural tendency to putrescence. Cooked in this state, it forms highly objectionable food for those predisposed to scurvy or putrid diseases, and should never be partaken of unless with the addition of vinegar, acid of lemons, or some other corrective. The flesh of *hares* was in high repute among the ancients, both in dietary and in medicine. The youngest and fattest are the best; and those bred on plains and mountains are preferable to those that live in moist places—the former feeding on aromatic herbs, which gives to their flesh a peculiar flavour. *Rabbits* are in more common use than hares; and in certain districts of the country no man who has tenpence or a shilling to spare need be in want of a pair to furnish himself and family with a nice Sunday dinner. Rabbits are either found wild in warrens, or are reared in sheds and hutches, as directed in No. 41. The former furnish the most dainty and agreeable food—having a greater opportunity of feeding on sweet aromatic herbs—such as thyme, juniper, and the like, which imparts to their flesh a rich and more pleasant flavour. Though a rabbit is in many respects similar to a hare, yet the flesh of the former is more tender, as well as more juicy, than that of the latter, and after boiling, becomes pale, and may be termed *white meat*. On the whole, it affords a good and nourishing diet, if taken at a middling age and size: when too young, it is not esteemed wholesome; and when old, it becomes dry, hard, and difficult of digestion. Rabbits are in prime season from the middle of October till the end of January.

Poultry—Game-birds.—So far as experience goes, the flesh of all birds is edible, though that of some tribes is less palatable and wholesome than that of others. As an article of food, it is pretty largely consumed in this country—the domestic fowl, turkey, goose, duck, pigeon, partridge, grouse, and pheasant, being the species which afford the chief supply. According to Brande, 100 parts of chicken-flesh yield 73 water, 20 albumen or fibrin, and 7 gelatine—that is, a total of 27 per cent. nutritive matter. Schlossberger's estimate is somewhat less; but of course chemical analysis will differ according to the condition, age, and other particulars of the specimen examined. The pectoral muscles which move the wings are drier and more tender than those which move the legs. The tendons of the legs are also very strong, and at a certain age become bony; but the flesh of the legs, when sufficiently tender, either from the bird being young, or from long keeping, or sufficient cookery, is more juicy and savoury than that of the wings. Of a few birds, especially the woodcock and snipe, the legs are at all times preferred to the breast. In the black-cock, the outer layer of the pectoral muscle is of a dark-brown colour, while the inner is white. A similar difference is observed in many other birds, and perhaps it is general in a slight degree. The muscular organs of birds differ from those of quadrupeds in their flesh never being marbled, or having fat mixed with the muscular fibres.' This is so far advantageous, as the fat of most birds, the aquatic in particular, is extremely difficult of digestion and assimilation.

It is usual for writers on dietetics to classify the flesh of feathered animals according to its colour, or according to the leading habits of the birds as regards their food and mode of life. Adopting some such distinction, Dr Pereira makes the following generalisations: 'The meat of the common fowl, turkey, and the like, is *white-coloured*, contains but little osmazome, when good, is generally liked, and when young, is exceedingly tender. Chicken flesh is nutritious, and when young, is perhaps the least stimulating of animal foods. It is often retained on the stomach of invalids when other meats would be immediately rejected. Chicken-broth is well adapted for irritable stomachs. The flesh of the wild gallinaceous birds, as the grouse, blackcock, &c., is *darker coloured*, firmer, richer in osmazome, somewhat less digestible, and more stimulating than that of the chicken. When sufficiently kept, it acquires a peculiar odour, called *fumet*, and an aromatic bitter taste, most sensible in the back. In this condition, it is said to be *ripe* or *high*, and is much esteemed by epicures as a luxury. The flesh of aquatic fowl, as the goose and the duck, is mostly firm, penetrated with fat—which often acquires a rancid and fishy taste—and is more difficult of digestion. It forms, therefore, a less appropriate aliment for invalids.' On the whole, it may be remarked that the younger and smaller the bird, the

more delicate and tender the flesh; but the female is generally more tender and delicate than the male; that domestication renders birds more fleshy and tender; and that the more cleanly and carefully the animals are reared, the more wholesome and palatable their flesh becomes. It may be also added, as the result both of experience and experiment, that poultry is more easily digested when broiled; is somewhat less digestible when roasted; and is least easily digested when boiled. The less it is mixed and qualified by sauces, stuffings, &c., the better.

The eggs of birds—the hen, duck, goose, and turkey—are largely consumed in Britain, partly as a direct article of diet, and partly in puddings, pastry, and fancy-breads. It is scarcely necessary to observe that the egg of the common fowl is that most extensively used, both on account of its superior flavour and digestibility. Both the white and yolk consist chiefly of albumen, the former almost entirely so. Thus, 100 parts of white of egg yield about 80 water, 16 albumen, and 4 incoagulable mucilaginous matter; the yolk about 54 parts water, 18 albumen, and 28 a peculiar yellow oil. The white, upon an average, is about twice the weight of the yolk; and deducting from the weight of the whole egg one-tenth for the weight of the shell, and the half of the remaining nine-tenths for water, and less than a fourth of the further remainder for the oily portion of the yolk, about a third of the entire egg appears to consist of azotised or nutritious matter.

With respect to the eligibility of eggs as an article of diet, much depends upon the mode of preparation. 'If lightly boiled,' says Dr Robertson, 'the digestion of the yolk of egg is hardly ever felt. Not so the white: when boiled, this almost always irritates the disordered stomach, and by the dyspeptic and invalid, it should not be eaten. The same observations apply to some extent to eggs when made to form part of a pudding: the yolk is still the part which is most easily digested—the white that which is the more likely to disagree; but the latter is not so likely to prove injurious as when eaten alone, and unmixed with other things. The probable reason of this is the same as that assigned for the increased digestibility of milk when mixed with flour or oatmeal; the albumen being prevented from coagulating into large masses, is offered to the action of the gastric secretions in smaller portions, which are therefore more readily acted upon by it. It is an important fact, that either the white or the yolk of egg, if eaten raw, and therefore uncoagulated, is much more easily digested than when it has been previously boiled. The albumen is of course, in this case, coagulated by the acid secretion of the stomach, as the first step to its digestion; but this coagulation is different from the coagulation by heat, and does not offer the same degree of resistance to the solvent powers of the stomach. A raw egg is not, then, liable to the objections, on account of its degree of digestibility, that a boiled egg may deserve; and, on the contrary, it would seem that there are few articles of diet which are so quickly or so easily digested as uncoagulated albumen. Lightly poached egg is probably more digestible than egg boiled in the shell; and this may be owing to the more rapid coagulation of the albumen, and the shorter time it is necessary to expose the albumen to the heat, in order to render it sufficiently cooked for palatability. It is hardly necessary to say, that fried eggs, involving the addition of fat, part of which is necessarily browned—that is, burned or converted into empyreumatic oil, and likewise involving the exposure of the albumen to a much higher temperature than that of boiling-water, must be much less easily digested than boiled eggs. The digestibility of egg is much influenced by its having been recently laid. Containing so much azotised matter, and the usual proportion of sulphur and phosphorus, egg soon undergoes the changes of decomposition; and probably to a considerable extent before these are to be detected by the sense or smell.'

Turtle.—Of the reptiles, which rank next in the descending scale of animated life, none can be regarded as a staple of food in this country. We leave the edible frog to our continental neighbours, and the turtle to the inhabitants of those regions of which it is a native. As a luxury, however, turtle is consumed by the wealthy and great, and is yearly becoming more common, as the facilities of steam-navigation bring it in much better condition, and much more abundantly. When cooked, the flesh of the green or edible turtle somewhat resembles that of chicken or veal; is pale, watery, soft, rich in gelatine, poor in fibrin, and contains little or no osmazome. It is said to be of easy digestion, and nutritive; and by decoction, yields highly restorative soups. The eggs of several of the turtle family are eaten as a palatable article of food.

Fish—Crustacea and Shell-fish.—This division embraces a large amount of the food of our countrymen, and is steadily, though slowly, on the increase. In the articles ANGLING and FISHERIES, the natural history and modes of capture of the fishes chiefly consumed in Britain are sufficiently detailed; we shall here restrict ourselves to their dietetic condition and importance. Unlike the flesh of birds, that of fish is not always to be eaten with impunity. Many, indeed, are highly poisonous; and even the best are not always in season. They are said to be in season after full recovery from the operation of spawning, up to the time when the roe and milt are ripe, and about to be shed—and the nearer this point the better. Almost every portion of the common edible fishes is available as food; but the muscular, fleshy, or flaky part is that which forms the staple. It differs little in composition in the various kinds, being composed mainly of water, albumen, and gelatine. Thus, 100 parts of cod-flesh yield 79 water, 14 albumen or fibrin, and 7 gelatine; and that of the sole, 79 water, 15 albumen, and 6 gelatine. In many fishes, this flesh is mixed or covered with fat or oil, as in the salmon, herring, pilchard, &c.; but after the spawning season this fat is greatly diminished: in others, as the cod, skate, &c., the fat seems concentrated in the liver, leaving the flesh devoid of it. Fish-flesh contains, theoretically, a fair amount of nutritive matter; but this is greatly depreciated in many instances by its indigestibility. Taken in the aggregate, Dr Robertson arranges their relative indigestibility thus: 1. White-fleshed fish; 2. Flat-fish; 3. Shell-fish; 4. Fresh-water fish; 5. Red-fleshed fish; and, lastly, the more oleaginous fish. From the quantity of water which the flesh of fish contains, it is less satisfying to the appetite than butcher-meat or poultry, at the same time that it is less substantial and nourishing. Besides the albumen, gelatine, mucus, and oil usually found in the substance of fishes, there are phosphates, chlorides and iodides of lime, magnesia, soda, &c., which may give to it peculiar dietetic and medicinal properties.

For dietetic purposes, fishes have frequently to undergo some sort of preparation, varying according to the situation, the necessities, or the tastes of the consumers. 'When circumstances permit,' says Dr Fleming, 'they are in general used in a *fresh* state; and in large cities, where the supply must be brought from a distance, various expedients are resorted to, to prevent the progress of putrefaction. By far the best contrivance for this purpose is the well-boat, in which fish may be brought to the place of sale even in a live state. Placing the fish in boxes, and packing with ice, is another method, and has been extensively employed, particularly in the supply of the metropolis with salmon. In many maritime districts where fish can be got in abundance, a species of refinement in taste, or at least a departure from the simplicity of nature, prevails, to gratify which the fish are kept for some days until they

begin to putrefy. When used in this state, they are far from disagreeable, unless to the organs of smell. Where fish are to be procured only at certain seasons of the year, various methods have been devised to preserve them during the periods of scarcity. The simplest of these processes is to *dry* them in the sun. They are then used either raw or boiled, and not unfrequently, in some of the poorer districts of the north of Europe, they are ground into powder, to be afterwards formed into bread. But by far the most successful method of preserving fish, and the one in daily use, is by means of salt. For this purpose they are packed with salt in barrels, as soon after being taken as possible. In this manner are herrings, pilchards, cod, and salmon, as well as many other kinds of esculent fish, preserved. The fish, in many instances, after having been salted in vessels constructed for the purpose, are exposed to the air on a gravelly beach, or in a house, and dried. Cod, ling, and tusk so prepared, are termed in Scotland *salt-fish*. Salmon in this state is called *kipper;* and haddocks are usually denominated by the name of the place where they have been cured. After being steeped in salt, herrings are in many places hung up in houses made for the purpose, and dried with the smoke of wood. In this state they are sent to market under the name of *red-herrings*. Although salt is generally employed in the preservation of fish, whether intended to be kept moist or to be dried, vinegar in certain cases is added. It can only, however, be employed in the preservation of those fish to which this acid is served as a sauce.' By the above processes of salting, drying, and smoking, the digestibility of fish is greatly impaired; though in some cases they may thereby be rendered more palatable and nutritious.

But though salting may thus impair the digestibility of fish, by hardening the fibres of the flesh, yet fresh fish are recommended by physicians to be eaten with a considerable quantity of salt. When salt is eaten with fresh fish, according to Dr Robertson, 'the fibres are not hardened by the salt; and the only effect of the salt is to stimulate the stomach so far as to promote or produce its speedy digestion. The more greasy the fish, the more salt should be eaten with it, and vinegar is usually a palatable and advisable addition. It answers the same end as salt, in correcting the effect of the fat, &c.; but this remark, it must be observed, applies only to such stomachs as can bear a moderate degree of acid without inconvenience. Broiling and boiling, especially the latter, are undoubtedly the best ways of cooking fish, both for wholesomeness and digestibility. Fried fish, from being cooked in butter or fat, is much less digestible. If the fish be not of a greasy character, broiling is the most digestible mode of cooking it; if greasy, the fat is rendered more or less empyreumatic, and by so much less wholesome, by broiling—and boiling is then the way of cooking it. With the exception of salt—and in the case of oily fish, of sugar—all addition to fish, in the form of sauce or condiment, of necessity renders its digestion more difficult. The melted butter with which fish is almost invariably eaten, must render it less digestible; and the dyspeptic who will eat fish, should not add to it butter in any form.

'The same observation, as to difficulty of digestion, is applicable to all the different kinds of shell-fish and crustacea. Muscles, cockles, &c., are less easily digested than oysters, and it is quite a mistaken notion that these are comparatively harmless in this respect. Prawns, shrimps, &c., like the lobster and crab, have hard, dense fibres, that are not readily dissolved by the gastric secretions. The character of the fibres, indeed, will afford a trustworthy guide—other circumstances being equal—to the digestibility of the different kinds of fish. Thus the denser fibres of the skate render this fish less digestible than the turbot; and the same circumstance makes the halibut less digestible than the salmon.' As to the nutritive properties of crustacea and shell-fish, they are in general greatly over-rated. In the oyster, for example, 100 parts of the flesh yield about 88 water, and only 12 of solid or nutritive matter; while 100 parts of butcher-meat yield, on an average, from 25 to 28.

Milk—Butter—Cheese.—These are indirect animal products, all largely consumed in every country, whether savage or civilised. Milk, which is obtained only from the class Mammalia, and intended by nature for the nourishment of their young, is the basis of the whole—furnishing, according to certain changes, which it readily undergoes, cream, butter, curd, cheese, whey, and so forth. Intended by nature as the sole food of the young mammal, it necessarily contains all the elements of respiration and nutrition. Blood, flesh, bones, and every other tissue, are formed from its elements: it is, in fact, a perfect food—that is, perfect in its kind, up to a certain stage of animal development. Its proximate constituents are caseine, butter, sugar of milk, various salts, and water; and these differ not only in various animals, as the following analyses will shew, but also according to the food, the age, and the period after parturition. Thus 100 parts of

	Caseine.	Butter.	Sugar.	Salts.	Water.
Cow's Milk yield .	4·48	3·13	4·77	0·60	87·02
Ass's " .	1·82	0·11	6·08	0·34	91·65
Woman's " . .	1·52	3·55	6·50	0·45	87·98
Goat's " .	4·02	3·32	5·28	0·58	86·80
Ewe's " . .	4·50	4·20	5·00	0·68	85·62

Such analyses, however, are to be regarded only as approximations, for the food, age, &c., must ever be taken into account. A cow fed on carrots, for example, yields a milk differing from that which she produces when fed on beet-root:

	Caseine.	Butter.	Sugar of Milk.	Salts.	Water.
Carrots, . .	4·20	3·08	5·30	0·75	86·67
Beet, . . .	3·75	2·75	5·95	0·68	86·87

Notwithstanding these differences, there is always in the milk of a healthy mother sufficient nutriment for the young; the cream and butter yielding fat, which, along with the sugar, subserves the purposes of respiration or heat; the caseine the elements of nutrition and growth; and the salts—chiefly phosphates of lime, magnesia, soda, and iron—matter for the construction of the solid skeleton. Milk as an article of diet for adults, is obtained in Britain almost solely from the cow; goat and ewe milk being only occasionally used in the preparation of cheese; whilst that of the ass is partaken of by invalids.

Referring the reader to the article DAIRY for the management and preparation of milk, cream, butter, cheese, and the like, we shall here merely advert to the respective dietetic peculiarities of these preparations. Cow's milk, when obtained from healthy, well-fed, and properly kept animals, is a very useful and valuable article of food, as well for adults as for children. Its principal drawback, according to Pereira, is the difficult digestibility of its fatty constituent, or butter—an objection, however, which can be got rid of by using it in the *skimmed* state. Under the name of *milk-diet*, it is extensively employed in conjunction with bread, oatmeal, rice, sago, potatoes, and other farinaceous substances, and forms in every case a readily assimilated and nutritive aliment. *Cream* consists of butter, curd, and serum or whey, and though less digestible than milk, properly so called, is not so liable to this objection as butter. Fresh *butter* is more easily digested than salt; and whether salted or fresh, preference is always to be given to that most recently prepared. *Whey* is chiefly composed of water and lactic acid, with a slight

proportion of caseine, butter, and sugar. It is therefore very slightly nutrient, but forms an excellent diluent in inflammatory complaints, and also gently promotes the secretions. *Butter-milk*, as containing the caseine, the sugar, and the salts of milk, must possess nutritive properties. It is deserving of wider adoption, both as an article of diet, and as a cooling and agreeable beverage. *Curd* is less easily digested than cream; but more so than butter. It consists mainly of caseine, and this from fresh milk yields 54·83 carbon, 7·15 hydrogen, 15·63 nitrogen, and 22·39 oxygen and sulphur. *Cheese*, or caseine dried, and having probably undergone some chemical change during the process of 'ripening,' is generally very difficult of digestion. It usually contains a considerable proportion of the fatty part of the milk, and in some cases is made almost entirely from cream. The impunity with which many persons can eat toasted cheese may be partly attributed to the mustard, &c., eaten along with it, although the cooking has much to do with the greater digestibility. Cheese made from cow's milk is more easily digested than that from goat's milk; and the richer or more oleaginous the cheese, the more easily is it digested. Ripe cheese is preferable to that which is green or immature, and also to that which is partially decayed. In whatever stage, cheese should be eaten with caution, as apt to produce not only indigestion, but crudity and consequent irritation in the intestines. It will thus be observed that none of the artificial or secondary preparations from milk possess its own bland and generally unobjectionable character, and this arises from the fact of their being concentrated forms of certain principles, while in milk these principles are mingled and diluted in right and natural proportion.

Animal fat, like the oil of vegetables, consists essentially of carbon, hydrogen, and oxygen; and therefore, when taken as food, can supply only respiratory or heat-forming matter. Containing about 80 per cent. of carbon, *heat-producing* is its proper function, and thus is explained the fact why the inhabitants of cold climates can consume with impunity so much of this aliment. All fatty matters are digested with difficulty, and are apt to irritate and derange the stomach and its functions. The fat of different animals, however, differs in point of digestibility; and, what is more curious still, differs also according to the part of the animal from which it is taken. The digestibility of fat is much affected by modes of cooking; it is also greatly modified by the action of vegetable acids and of common culinary salt.

MINERAL FOOD.

It has been already mentioned that man derives little of his food directly from the mineral world. No doubt all plants and animals contain a certain amount of saline and earthy ingredients, which are indispensable to healthy aliment; but those are indirect products, and are always taken into account when estimating the relative dietetic value of vegetable and animal compounds. In fact, the only substances obtained directly from the inorganic kingdom, and consumed in large quantities, are water and salt—two substances as necessary to existence as the air we breathe. The former, as has been seen, enters largely into the composition of every species of food; it acts as a solvent and diluent in all cases, and permeates everywhere the tissues to whose subsistence and growth it administers. The latter, though usually taken as a palatable condiment, is really essential to the maintenance of health and vitality, and accordingly appears as a constituent of the blood and the tissues elaborated therefrom.

Water, as consumed by man either as a beverage or as a constituent of his food, is generally in a fresh state; that is, contaminated as little as possible by foreign ingredients. The nature and constitution of water have been already detailed under the heads CHEMISTRY and SUPPLY OF WATER: all that is necessary to be here observed is, that the supply for dietetic uses should be freed from all mechanical impurities, and from all chemical impregnations, which may render it unpalatable, unsuitable for culinary purposes, or detrimental to the system of the consumer. Absolutely pure water is not found in nature, nor does it indeed seem to be required by the animal economy. It is only pure when distilled, and in this state it is neither pleasant to the taste nor wholesome. The purest waters always contain some amount, however small, of common salt, lime, iron, and other saline matters; as also organic matter. It is only when these foreign substances exist in large amount that water becomes objectionable. Good water is generally known by its softness, its limpid and somewhat sparkling appearance, its agreeable flavour, and its non-liability to become putrid. Its softness it acquires from the absence of saline or mineral ingredients, its sparkling aspect and agreeable flavour from the carbonic acid which it has absorbed from the atmosphere, and its resistance to putrescence from the comparative absence of animal or vegetable matter. By filtration, which is now generally practised, all mechanical impurities can be got rid of; but for the removal of the more objectionable chemical impregnations, boiling, or the admixture of chemical re-agents, is required.

The ordinary sources of fresh-water are rains, springs, rivers, lakes, and wells; and according as it is obtained from one or other of these sources, so is it characterised by peculiar properties. *Rain-water*, if collected in mountain districts, far from human dwellings, is perhaps the purest of all; but if collected in the neighbourhood of towns, it is found to be largely impregnated with soot and other extraneous substances; and the rapidity with which it putrefies, demonstrates the presence likewise of organic matter. Being soft, it is valued by the housewife for washing; but is unfit for internal or culinary purposes without undergoing rigid filtration. Unimpregnated with mineral substances, its action on lead is more rapid than that of other waters, and it should never, therefore, be kept in lead cisterns. All *spring-water* is less or more impregnated with the substances through which it has percolated to the surface; but with the exception of those commonly termed 'saline' or 'mineral'—and which are noticed under MEDICINE—most springs yield water of sufficient purity for domestic purposes. Those issuing from the primitive and igneous rocks, or from extensive beds of sand and gravel, are generally the purest; those from the carboniferous and other secondary strata are not so free from impurity. *River-water*, which is an accumulation of rain and spring water, is often well fitted for human purposes. Its impurities are both of a mechanical and of a chemical kind; the former may be removed by careful filtration. Much, however, depends upon the soil and district through which the river flows; meadows, morasses, and forests yielding organic matter, and factories and towns bequeathing heterogeneous impurities, not to be got rid of by any ordinary process. Water drawn from fresh *lakes* is less turbid than that from rivers; but is always—unless from deep mountain tarns—more largely impregnated with vegetable and animal matter. *Well* or *pump water* is that obtained by boring or by sinking shafts into rocky strata. It must, of necessity, like spring-water, partake more or less of the mineral ingredients through which it percolates; and is not unfrequently injured by the pumps, pipes, and other apparatus by which it is raised. Such are the ordinary sources from which man derives his dietetic waters; and it were greatly to be desired that more efficient modes of purification, as well as abundance of supply, were more generally adopted in reference to our towns and cities, which, with few exceptions, have neither quantity nor quality to boast of.

Respecting the alimentary functions of water, Dr Pereira, after remarking that it is the natural drink

of all adults, observes: 'It serves several important purposes in the animal economy: *Firstly*, It repairs the loss of the aqueous part of the blood, caused by evaporation and the action of the secreting and exhaling organs; *Secondly*, It is a solvent of various alimentary substances, and therefore assists the stomach in the act of digestion, though if taken in very large quantities, it may have an opposite effect, by diluting the gastric juice; *Thirdly*, It is probably a nutritive agent —assisting in the formation of the solid parts of the body. It has not, indeed, been actually demonstrated that water is decomposed in the animal system; or, in other words, that it yields up its elements to assist in the formation of organised tissues; yet such an occurrence is by no means improbable. It appears from Liebig's observations, that the hydrogen of vegetable tissues is derived from water; and it is not probable that the higher orders of the organised kingdom should be deficient in a power possessed by the lower orders. Dr Prout appears to admit the existence of this power, but thinks that it is rarely exercised by animals. The water which constitutes an essential part of the blood and of the living tissues, assists in several ways in carrying on the vital processes. "In the blood," says Prout, "the solid organised particles are transported from one place to another; are arranged in the place desired; and are again finally removed and expelled from the body, chiefly by the agency of the water present." It is from water that the tissues derive their properties of extensibility and flexibility. *Lastly*, This fluid contributes to most of the transformations which occur within the body. As a solvent, it serves not only to aid digestion, but also to effect other changes, as, for example, the conversion of uric acid into urea, and sugar or starch into sugar of milk and diabetic sugar. So, also, the hydrochloric acid of the gastric juice, and the soda of the blood and bile, are derived from common salt (chloride of sodium) by the aid of water.'

Salt.—Referring the reader to our article on MINING AND MINERALS, for an account of the modes of procuring and preparing this indispensable article, we shall here strictly confine our remarks to its dietetic or alimentary importance. 'By virtue of its chlorine,' says a popular authority, 'salt largely promotes the functions of the stomach and bowels in assimilating the food; by virtue of its soda, it greatly subserves the uses of the bile in the economy; and in its every action —whether by means of its separated constituents, or in its combined state, serving probably to maintain the blood in its singularly compound and yet homogeneous condition—is shewn to be great on all the functions and conditions of the body. There can be no question, however, that even salt may be too much or too little used in the food: that in the one case, the tissues and the expending organs are too much stimulated; in the other case, the system is unduly, and not without serious risk, deprived of that agent, by which so large a share is performed in the nutrition of the body; and which in itself, by its ultimate elimination from the body in the several excretions, probably serves to keep up the action of the excreting organs, and promotes the disintegration and throwing off of the effete matters, no longer fitted for the purposes of the economy, and which could not be retained without injury. The less readily assimilated the articles may be, and the less of saline matter contained in them, the more essential is salt as a part of the food; hence the oily articles of food, and the purer forms of the starchy principle, when largely used as means of nutrition, require usually more salt to be eaten with them than the more ordinary and less pure forms of vegetable or even animal diet. And yet animal diet of any kind, probably from its putrescent tendency, if not mixed with vegetable food in sufficient proportion, is found to require a large mixture of salt with it, for the maintenance of health and strength.' The amount of salt consumed by a full-grown person has been estimated at sixteen pounds a year, or about five ounces a week; but of course this estimate will vary exceedingly, according to the tastes and habits of individuals.

All the varieties of salt, whether small-grained, like the *basket* or *table salt*, or in large crystals, like the *bay* and *fishery salts*, consist essentially of chloride of sodium, which is composed of 60 per cent. chlorine and 40 sodium. The salt of commerce, however, is never found absolutely pure, being less or more contaminated with salts of lime and magnesia, as well as insoluble matter. Thus an average of foreign bay-salts yielded to analysis 3½ per cent. of such impurities; British salt from sea-water upwards of 4 per cent.; and that from English rock-salt somewhat more than 1½ per cent. The purer salt is, of course the more wholesome will it be as an article of diet, and the more effectual for the purposes of pickling and curing provisions.

BEVERAGES.

Writers on dietetics are in the habit of classifying drinks or beverages according to their sensible, chemical, or medicinal properties. Thus we have—1. Mucilaginous, farinaceous, or saccharine drinks; 2. Emulsive or milky drinks; 3. Animal broths, or drinks containing gelatine and osmazome; 4. Aromatic or astringent drinks; 5. Acidulous drinks; and, 6. Alcoholic and other intoxicating drinks. Water, however, is the only true natural beverage: it forms the basis of the whole of the above—the other constituents being but infusions, decoctions, and solutions of solid elementary substances already described. Being reduced to a liquid form, the alimentary action or effect of these substances is much facilitated, and thus, in point of easy assimilation, beverages are immensely superior to solid food. In certain cases, therefore, it is advisable that diet should be taken in this form; not only on account of its ready assimilation, but from the accuracy with which it can be reduced to the necessary strength. In all cases, however, of healthy existence, food in a solid form is indispensable, and beverages are to be regarded simply as diluents, demulcents, and correctives. Setting out with this view, and following the above distinctions, we shall now briefly allude to the more abundant and familiar beverages—adopting as authorities Liebig, Pereira, and Robertson:

1. The mucilaginous, farinaceous, and saccharine drinks are perhaps the simplest, next to water. They are merely solutions, infusions, or decoctions of substances already described, and are known by such terms as *gum-water*, *toast-water*, *sugar-water*, *barley-water*, *mucilage of rice*, and *gruel* from oats, sago, arrow-root, or tapioca. They are all very slightly nutritive; and are used chiefly in the sick-chamber as demulcents and diluents. Toast and barley waters are placed by the faculty at the head of this division.

2. Emulsive or milky drinks are such as hold in suspension any oily or fatty substance in a finely divided state. *Animal milk* (already described) is at the head of this section; others, as *milk* and *sirup of almonds*, fall more properly to be noticed under MEDICINAL PREPARATIONS.

3. Broths and soups, or drinks containing gelatine and osmazome, are usually prepared from beef, mutton, veal, and chicken. A number of receipts are given for their preparation in the article COOKERY; the rationale of their aliment has been already described. Boiled meat of good quality yields kreatine and osmazome, coagulated albumen, gelatinous cellular tissue, fatty matter, saccharine matter, some salts and water; and to prepare a soup so that none of these may be

dissipated and lost, is the chief point requiring attention. When pot-vegetables, as turnips, carrots, onions, barley, &c., are used, of course these communicate new principles to the liquid—as mucilage, sugar, azotised products, volatile oil, and salts. Extract of the pure or lean meat is always preferable for invalids and convalescents —*beef-tea* and *chicken-broth* being the most highly recommended.

4. Of the aromatic and astringent drinks, tea, coffee, and chocolate are pre-eminently the most familiar. 'We shall never, certainly, be able to discover,' writes Baron Liebig, 'how men were led to the use of the hot infusion of the leaves of a certain shrub (tea), or of a decoction of certain roasted berries (coffee). Some cause there must be, which would explain how the practice has become a necessary of life to whole nations. But it is surely still more remarkable that the beneficial effects of both plants on the health must be ascribed to one and the same substance, the presence of which in two vegetables belonging to different natural families, and the produce of different quarters of the globe, could hardly have presented itself to the boldest imagination. Yet recent researches have shewn, in such a manner as to exclude all doubt, that *caffeine*, the peculiar principle of coffee, and *theine* that of tea, are in all respects identical.' The fact is certainly striking enough, and all the more so that cocoa or chocolate also yields a principle (*theobromine*) identical, or all but identical with theine and caffeine. These principles furnish elements precisely the same as those of the bile; hence their effect on the processes of secretion, on nutrition, and vitality.

Tea is usually distinguished as *black* or *green:* the former including such marketable varieties as Bohea, Congou, Souchong, Caper, and Pekoe; the latter, Twankay, Hyson, Imperial, and Gunpowder. Of the black teas, Pekoe is one of the best; of the green, Gunpowder. When subjected to analysis, they all yield less or more volatile oil, chlorophyle or colouring matter, wax, resin, gum, tannin, theine, albumen, lignin, and extractive matter. The dietetic and medicinal properties of tea are thus detailed, throwing out of view the qualities usually imparted by the addition of sugar, milk, or cream:—It acts on the system as a stimulus or a sedative, according to the strength of the infusion that is taken. When taken in smaller quantity, its effect is, in general, simply and in a small degree sedative, even in the first instance; when used in larger quantity, its primary action is decidedly that of a stimulus. Its well-known effect of inducing wakefulness illustrates this. To many people, when taken late in the evening—and in some when taken strong at almost any time—it produces a very sensible degree of stimulation, and a state of sleepless excitability. Besides inducing wakefulness, tea seems to sharpen the mental faculties, and perhaps, in an especial degree, the imagination. Green tea has, generally speaking, more stimulating, black tea, more sedative properties. The stimulating effects are, however, always and necessarily followed by sedative effects, which may amount in extreme cases to depression, or even to a degree of narcotism; and in most cases it acts as a narcotic on the organs of excretion, producing more or less visceral torpidity and sluggishness. To the man who has a sufficiency of nourishing and wholesome food, the use of tea in moderate quantities, and at proper times, cannot be said to be ever followed by unpleasant or unsatisfactory consequences. If taken in excessive quantities, tea becomes decidedly debilitating to the nervous system, affecting it much in the same way as any other stimulant and narcotic. But though tea, when used in moderation, is serviceable to the individual who takes a sufficient quantity of nutritious food, unquestionably serving some important purpose, in completing and perfecting the last stages of digestion; and although, under such circumstances, the use of tea is not injurious, this is by no means the case when the aliment that is taken is deficient in quantity or of too poor a quality. Under such circumstances, tea acts on the nervous system to a degree that is often productive of disorder, and which probably sometimes leads to disease. The effect of tea on the second stage of digestion, and probably on the secretion of the bile, points out and explains its value when taken about three or four hours after the principal meal of the day, and illustrates the well-known anxiety of the dyspeptic for tea-time, and the comparative comfort he enjoys after this beverage, which is aptly said 'to cheer, but not inebriate.' Taken at the same time as a heavy meal of food, or such a meal as contains a large proportion of the day's alimentary supply, tea may prove to be too much of a diluent, or too directly narcotic; and in some cases may rather retard the primary digestion than otherwise. This, however, depends very much on the quantity and the strength of the infusion made use of. Green tea, although said to be used almost exclusively in some countries, is found to be much too narcotic and stimulating for exclusive use in this country, and is necessarily forbidden to most invalids, from its evidently enervating effects.

The *Coffee* of commerce is the seed of a berry-bearing tree or shrub, found originally in Arabia, but now extensively cultivated in all tropical countries. It is usually distinguished by the place of its growth—as Mocha, Jamaica, Mountain-Jamaica, Demerara, Ceylon. Raw coffee can be kept for any length of time without deterioration—indeed, the older the better; but on being roasted, it develops a fragrant and aromatic principle, which is extremely volatile. Roasted coffee should therefore be ground and used as speedily as possible. Coffee yields to analysis caffeic acid, tannic acid, caffeine, wax, resin, gum, albumen, lignin, extractive matter, and salts of lime, magnesia, and iron. Its dietetic properties and peculiarities are thus detailed by the preceding authority: Used in infusion or decoction, coffee is more nutritious than tea, but is more difficult of digestion. Whether owing to the tannin, which the roasted coffee is said to contain, or to the aromatic oil, or the mucilage, or the bitter extract, or to the combination of these different constituents, coffee deranges considerably the stomachs of some people, and is usually somewhat difficult of digestion to invalids and to those who are more seriously dyspeptic. It is probable that this is not referable to the aromatic principle, as the best coffee, which contains more aroma, is less likely to disagree than the commoner sorts. The infusion is usually less apt to disagree than the decoction, unless the latter have been most carefully clarified. The consequence of coffee proving to be of difficult digestion, is rather to produce considerable acidity than to give rise to any other marked dyspeptic symptom. Supposing that coffee does not disagree, which in the healthy and strong it seldom does, it is a peculiar and decided stimulus, quickening the circulation, promoting the secretions and excretions, very perceptibly warming the system and elevating the spirits. Supposing that the powers of the digestive organs are adequate to its complete assimilation, coffee, from being much more nutritious, and more decidedly restorative to the system, forms a better addition to other articles of food that are taken at breakfast than tea. If its ready digestibility be suspected, the question of its being mixed with sugar, and the known difficulty with which sugar is digested, should be considered before coffee is pronounced to be unsuited to the individual. The addition of milk to coffee adds much to its nutritiousness, diminishes in some degree its directly stimulating effects, and seldom makes its digestion more difficult. As to the addition of *chicory*—the roots of the wild succory, or endive, dried and ground—now so commonly practised, medical authorities are rather in favour of a moderate admixture than otherwise. The chicory-root is perfectly wholesome, contains no alkaloid or oil, and only a small amount of resinous and narcotic

matter. When added in small quantities, it rather improves the flavour of coffee, apparently combines with, or neutralises its oil, and altogether renders it less difficult of digestion.

Cocoa is derived from the seeds or nuts of the chocolate-tree (*Theobroma cocoa*), a native of tropical regions. The seeds grow in pods, and are prepared for use by being roasted, deprived of their husks, and ground. Cocoa is either used in the form of the ground seeds, simply made into a decoction; or these are ground into a paste, mixed with cloves, cinnamon, vanilla, &c., forming *chocolate*. In either form, cocoa is described as oleaginous, and somewhat acrid, and is in general by no means so easily digested as tea or coffee. Still, there are many people, both dyspeptic and sedentary, with whom it invariably agrees; and this much can be said in its favour, that it is devoid of the disagreeable qualities of disturbing the nervous functions. The ground seeds are preferable to the paste or cakes, of whose composition, or, we should rather say, adulteration, we are ignorant.

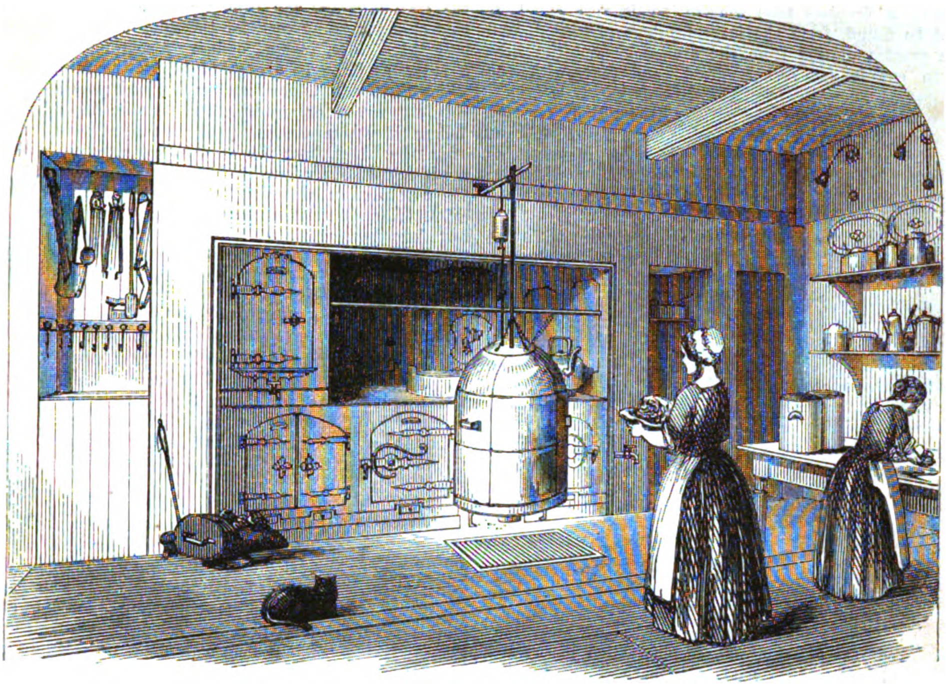
5. The acidulous beverages in common use are *lemonade*, *ginger-beer*, *soda-water*, *effervescing saline draughts*, *Seidlitz powders*, and the like. Their action being medicinal and corrective, rather than alimentary, their consideration properly belongs to a subsequent number. When prepared from the acid juices of fruits —as lemon, raspberry, apple, &c.—they form cooling, refreshing, antiscorbutic drinks, and are well adapted for hot seasons and for febrile and inflammatory cases. When compounded of some alkali and acid, like the common effervescing draughts, they are also slightly aperient.

6. Beverages which are the products of fermentation are usually classed as *spirits*—brandy, gin, whisky, and rum; *wines*—port, sherry, claret, champagne, &c.; *liqueurs*—embracing all the sweet or home-made wines; and *malt liquors*—ale, porter, and beer.

Referring the reader to CHEMISTRY APPLIED TO THE ARTS, for the theory and principles of fermentation, we shall here merely allude to the alimentary or dietetic effects of these well-known, and in many cases, too largely consumed beverages. *Alcohol*, or the leading principle in spirits, consists of carbon, hydrogen, and oxygen; it contains no nitrogen, sulphur, phosphorus, or other ingredient capable of administering to growth or nutrition. Its function is that of a heat-former; it is merely an element of respiration, serving to support the temperature of the body. But in subserving this purpose, it stimulates, excites, and, if taken in any quantity, intoxicates; and the question for those in search of animal heat simply resolves itself into this —Can we not gain our end by means more simple, natural, and less dangerous? It has been well remarked, that 'though alcohol evolves heat in burning, it is an obnoxious fuel. Its volatility, and the facility with which it permeates membranes and tissues, enable it to be rapidly absorbed, and when it gets into the blood, it exerts a most injurious operation, before it is burnt in the lungs, on the brain and the liver. Though, by its combustion, heat is evolved, yet, under ordinary circumstances, there are other better, safer, and less injurious combustibles to be burned in the vital lamp.' It is only, indeed, as a restorative and corrective that its use is at all admissible; and there can be no doubt that in cases of extreme exertion and privation of food, the cautious and moderate dietetic use of spirits has on many occasions proved invaluable. *Brandy*, derived from the distillation of wine, is perhaps the least objectionable form in which alcohol is administered. Its constituents are alcohol, water, volatile oil, a minute quantity of acetic acid, œnanthic ether, and colouring matter. It is distinguished from other ardent spirits by its cordial and stomachic properties. *Rum*, distilled from molasses and sugar skimmings, is very similar to brandy in its effects, but more heating, and more disposed to cause sweatings. *Gin*, obtained from corn-spirit, and flavoured with juniper, sweet flag, &c., is, owing to the oil of juniper it contains, more powerfully diuretic than either brandy or rum. *Whisky*, also a corn-spirit, agrees in most of its properties with gin, but is somewhat lighter, and more stomachic.

Wine is the general term applied to liquors prepared by the vinous fermentation of the juice of the grape. 'The peculiar qualities of the different kinds of wine depend on several circumstances; such as the variety and place of growth of the vine from which the wine is prepared; the time of year when the vintage is collected; the preparation of the grapes previously to their being trodden and pressed; and the various manipulations and processes adopted in their fermentation.' Though thus varying, and known by a thousand names, the general constituents of all wines are—water, alcohol, volatile oil, sugar, gum, tannin, tartrate and bitartrate of potash, acetic acid, extractive and colouring matters, and carbonic acid, in the effervescing varieties. The amount of alcohol in wines is exceedingly varied: in claret, for example, it seldom exceeds 7 or 8 per cent. by weight; while in ports and sherries it ranges from 12 to 18 per cent. As to the dietetic properties of wine, Dr Paris asserts 'that there exists no evidence to prove that the *temperate* use of good wine, when taken at *seasonable* hours, has ever proved injurious to *healthy* adults.' Dr Pereira is by no means disposed to question this assertion, qualified as it is; but maintains, on the other hand, that 'for healthy individuals wine is an unnecessary article of diet. It may prove,' he continues, 'a valuable restorative when the powers of the body and mind have been enfeebled by fatigue; but, on the other hand, it cannot be denied that the most perfect health is compatible with total abstinence from wine; and that the habitual employment of it, especially by the indolent and sedentary, is calculated in many instances to prove injurious. Disorders of the digestive organs and of the brain, gout, gravel, and dropsy, are the maladies most likely to be induced or aggravated by the use of wine. Intoxication, in its varied and lamentable forms, is the effect of the excessive use of it.'

Malt liquor is the generic term for all fermented infusions of malt flavoured with the bitter principle of hops. Normally, they ought to contain less or more of alcohol, starch, sugar, dextrine or starch-gum, extractive and bitter matters, fatty, aromatic, and glutinous matters, lactic acid, carbonic acid, salts, and water. They are, however, often largely adulterated—molasses and other wash being used for malt, quassia substituted for hops, flavours imparted by capsicum, ginger, and coriander; and intoxicating qualities conferred by cocculus Indicus, nux vomica, and opium. Keeping out of view these adulterations, the genuine liquors are fitted by their constitution to quench thirst and act as diluents, to yield heat and nutrition, and to operate as tonics and stimulants. The only drawback to their use in large quantities is the intoxicating effect of their alcohol—common beer containing about 1 per cent. by measure of this spirit, porter from 4 to 6, and strong ale from 6 to 8.



Kitchen, with Close Range.

PREPARATION OF FOOD–COOKERY.

COOKERY is the art of preparing food. Much of our daily comfort and health depends on the way in which food is prepared. Every housewife may not be able to procure the finest kinds of food, but by attention, activity, cleanliness, and neatness, a great deal may be done to make even the plainest fare palatable and wholesome.

Boiling and Stewing Vessels are now to be had of every size and description; the best kind—called goblets in Scotland, and sauce-pans in England—are those made of iron, well tinned inside. It is convenient to have one or two of the very smallest dimensions, made of block tin; and also to have several to be kept for delicate stews or preparations, for which purposes those lined with delf are preferable. It is likewise advantageous to have a few shallow sauce-pans to be used for stews, or where little liquor is required; also one large fish-kettle, with a flat drainer to place below the fish in boiling, and for lifting to the dish when done. All the vessels should have tightly fitting tin or iron covers; and one or two should be fitted with perforated apparatus for steaming.

The *Kitchen-range* forms the most important part of the cooking apparatus, and without one that does its work well, we cannot have our food prepared satisfactorily. Great attention should therefore be paid in choosing one and fitting it up. As a very large proportion of those in use is faulty, it will be useful to give a few hints on their constructions, as well to those who may have to purchase new ones, as to those who wish the ranges already in their possession improved. And first, in regard to the fire, in a moderate establishment, the *open fire* is to be preferred to the *hot plate*, because it is simpler, and consequently cheaper; and also because, with some slight modifications which will be mentioned, it is really, in some important respects, more economical and efficient. The great objection to an ordinary open kitchen-fire is, that it consumes a great quantity of coals, and yet can only with difficulty be got to give the 'quick' sustained heat that is required for roasting and other culinary processes. The reason why a quick fire is essential to good roasting, is obvious. When we boil properly a leg of mutton, we put it into water brought to the boiling temperature, in order that the outer layer of albumen may be rapidly coagulated, and may thus form a crust which will retain the internal juices and savour of the meat; and so also, in roasting, if we wish these retained, and the meat properly done, we must have the fire quick before the meat is exposed to it. A proper heat is most effectually obtained, at the same time that a great saving in coals is effected, by using a *fire-brick*. This should be placed at a distance of not more than five or six inches behind the bars of the grate, to secure its great power in radiating heat, and, at the level of the bar which folds down, it should be shaped thus (as seen from the side), so that pots may rest either on the ledge, A, or on the top, B. The fire can thus be made broader at top when required. The thickness of the fire-brick should be about three inches, or, where there is a boiler behind, the shape can be made to correspond to it; and it will be found that the heat communicated to the boiler at the side, will be quite

Fig. 1.

sufficient to keep the water in it hot. Although the size of a fireplace thus constructed is very small, it will be found, from the large frontage presented, and the great radiation from the fire-brick, that the heat given out is surprisingly great; and that, with the 'dispatch' where the fire is small, or, where it is larger, with a tin screen to go before the fire, and the common simple apparatus of a spit, with two horizontal balls attached to a skein of worsted, almost all roasting processes can be managed easily and to perfection; for meat cooked in this way is always sweeter than when done in the oven.

The width of the fire, of course, will vary with the size of the range. Its breadth from the bar to the top of the fire-brick, B, is six or seven inches; which from the great heat given out, will be found amply sufficient for boiling processes. Increased accommodation for these and other purposes can be got by having a movable 'trevet'—on the side next the boiler, where there is one —on which can be placed small pots; and by having a firm bar of iron to go across the fireplace, immediately above the fire, at a height of about two feet above it. This is fixed in the mason-work of the two sides of the chimney, and three or four hooks are attached to it, from which pots can be suspended. Where this arrangement is adopted, the pots for stewing, &c., should have handles that can be attached to the iron bar. A good kitchen-range should have a boiler on one side—extending, if wished, behind the fire—and an oven on the other side. The frontispiece represents a very superior kitchen-range, fitted up with ovens, hot-plates, &c.; the fireplace, which is very small, is so arranged that a dinner may be cooked for thirty people, besides which it supplies enough of heat to keep water for a bath at a sufficiently high temperature. The apparatus is so constructed that the operations of boiling, roasting, stewing, frying, baking, and steaming may be carried on at one time. This range, however, is costly, and can only be recommended for the kitchens of the opulent classes; it is manufactured by Henry Goddard of Nottingham, who has devoted much time and attention to the subject. The proper heating of the oven, from the faulty construction of those seen in Scotland at least, is a matter of great trouble, and even difficulty, to the housewife. By attention to a few simple arrangements, a great heat may be obtained for it without any other fire than has been described; so great, indeed, that the top of it can be made, when wanted, to serve as a hot plate, at the same time that it is always ready for use at a minute's notice. To make this obvious, we shall, in a few words, describe the alterations we had made on one of a faulty construction. The range which came into our possession was of the common make, in which the oven had a fireplace beneath it, but with no communication with the fireplace of the range, though on the same level. It had been for years totally unworkable. All that was done to convert it into a splendidly working oven, which has been in constant use for many years, without once going out of order, was as follows: The fireplace under the oven was built up with care to the level of the fire-grating, and the ash-pit closed; a free opening was made from the fireplace of the range into that under the oven, and a sheet-iron tube, six feet in height—four or five feet will answer—was run up within the kitchen-chimney, from the top of the oven-chimney. This simple arrangement, it will be perceived by those conversant with such matters, gave a 'draught' of hot air through the range-fire, *when all other access to the external air was carefully closed;* and thus the oven can be kept constantly ready for use, without either cost or trouble. By adding to the fire occasionally, near the opening under the oven, a few pieces of fresh coal, a constant very high temperature can be kept up; which may be moderated, by opening for a short time the door under the oven. The most common cause of difficulty in heating the oven in defective ranges, arises from want of length, and consequent want of draught, in the oven-chimney, and from the tube forming part of this chimney being cast, for the sake of economy, with only three sides, instead of being a complete square, or circular, as it ought always to be, as the mason-work which is trusted to for forming the back portion of the tube, can never for any length of time be depended on. Where there is no opening from the range-fire under the oven, the latter, from the trouble connected with heating it, is practically found to be almost useless. Whatever the construction, therefore, this opening should always exist. Ranges constructed upon the principles which have been mentioned, and called 'The Self-acting Hot-air Kitchen-range, with Fire-brick,' may be ordered from any ironmonger. A small one costs about £2, and larger sizes cost in proportion.

Before entering upon the subject of cookery in a systematic form, it has been thought that it may be useful, especially for the working, and some of the middle classes, to mention a few principles of cookery, and to give some plain practical directions for the preparation of the homely fare which may be supposed to be the daily food of such families. This department we shall designate

COTTAGE COOKERY.

In Scotland, the dish almost universally used for breakfast by the working-classes and for children is oatmeal *porridge*, the oatmeal being rougher in the grain than is generally used in England. The fault commonly committed in making this excellent and wholesome article of food is in not boiling it sufficiently. Three-quarters of an hour's boiling is required to break down the meal, and render it properly digestible. Where the water is 'hard,' a very small bit of washing-soda accelerates the process; but this requires to be cautiously used. Churn or sweet milk, or a mixture of the two, is used along with the porridge.* Among the middle classes, the plate of porridge is often followed by a cup of coffee, which is calculated to correct the slight sluggishness which some persons feel after taking porridge alone.

Coffee to breakfast is now the article most commonly used by the middle classes in this country. It is preferable to tea when the latter is taken in the evening. Strong tea twice daily, for nervous persons especially, amounts to a species of dissipation, and produces upon some very unpleasant effects. The stimulus from taking coffee is more gentle and diffused, and is quite as long continued. To prepare really good coffee, is found by many housewives to be rather a difficult matter, and yet it is very easy if a few simple directions are attended to. The object in view is to get the coffee to impart to the water poured on it the slightly bitter and the aromatic principles which it contains, and to lose none of these. This is best done by pouring on the coffee in the coffee-pot boiling water, accurately closing the cover of the coffee-pot, and fixing a nozzle on its spout, and then placing the pot on the fire, and just allowing the water to boil. The moment steam appears, the coffee is made, and the pot must be taken off the fire. Coffee made in this way has the one disadvantage, that it is not so clear as could be wished. To obviate this defect, the white of an egg or isinglass is sometimes used; and in France a percolator is fitted to the top of the coffee-pot. The first, however, is troublesome, and the second is expensive, as a large quantity of coffee must be used to insure a sufficient extract of its qualities. There is a form of coffee-pot which has the percolator placed *in* and not *on* it, and which thus obviates the objection mentioned. It is of this

* For economy, some years since, treacle-beer was substituted in one of our penitentiaries for the milk; but this had to be discontinued, as an alarming outbreak of scurvy took place in consequence of the change.

construction. A is the coffee-pot with the nozzle fixed; B is a section of the same with the percolator, F, inserted, which easily slips into the coffee-pot, and rests on plugs at C, C; D is a small upper percolator, with a curved handle, which fits into the top of F, also resting

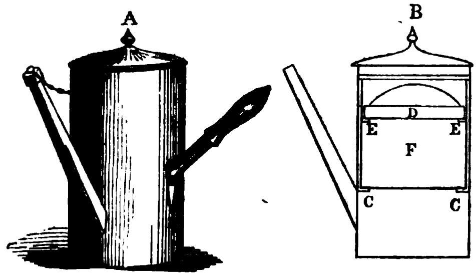


Fig. 2

on plugs, E, E. When coffee is made in this pot, the percolator, F, is placed in its situation within the pot; all the openings in the percolator are covered gently with coffee; the small upper percolator, D, is put in its place, and boiling water is poured through it on the coffee, in such quantity as may be wished. The cover and nozzle are immediately fitted on the pot, which is placed on the fire until steam appears at the spout and cover, when it is instantly withdrawn. In use, this pot is found to be very simple, and with it a pure and very fine coffee may always be had.* A fourth of foreign chicory imparts body and improves the quality of the coffee; and if these have not been got within a day or two after being roasted, they should be heated together over the fire in an iron pot before being used. Mr Soyer has made the important observation, that coffee thus heated, and tea heated in the teapot for ten minutes before infusing, are both in consequence made to part with their aromatic properties more readily. For breakfast, one-third of boiled milk should be used with the coffee, the latter of course being made proportionately strong; or cream alone, or with the milk, may be used when the coffee is wished richer. In infusing *Tea*, besides slightly heating it as mentioned, most housewives are aware that where the water is hard, a small quantity of carbonate of soda assists the process.

Fresh rolls—in winter, they should be heated in the oven—are now generally used among the middle classes, where there is the convenience for getting them. As relishes to the tea or coffee, the best are good salt, red, kippered, or Nova Scotia herrings, a Finnan haddock, an egg, a bit of fried smoked bacon, tongue, &c. In June, and the two or three following months, one of the great annual treats of this kind enjoyed by the population in the towns in the west of Scotland is the delicious Loch Fyne herrings, very slightly salted. To breakfast, or with young potatoes to dinner, almost nothing can be finer. They generally require to be steeped in cold water for a night, and are then used boiled, or 'reisted'—that is, hung up and dried, and done on the gridiron. This cheap and simple treat should be more extensively known to the working-classes. Among the most delicate of breakfast-dishes, when in season, are the 'rizzared' whitings or small haddocks. Rizzaring a haddock means simply cleaning it, slightly salting, and hanging it up to dry for a day or two.

Dinner in this country is generally considered the most important meal. In the south, the workman must have for it his bit of roast-meat or stew, with pudding, pie, or dumpling; while in the north he rarely tastes roasts or dumplings, and is content for the most part with 'broth and meat.' Perhaps each could, for the improvement of this meal, with advantage borrow some hints from the other. The Englishman would find it advantageous to have introduced at his table the wholesome vegetable soups so largely used in Scotland, while the Scotchman would experience both variety and satisfaction from having more of the savoury dishes in which his English neighbour delights.

* One for a family may be made 9 inches high, by 5½ wide, and smaller for one or two persons. Any tinsmith can easily make them from the section given, at a price varying from 2s. 6d. to 3s. 6d.

We shall first speak of *soups* as an article of diet. In making these, we constantly see violated, in the houses of workmen, the most obvious principles of good cookery and economy, to an extent which it is positively painful to think of. Let us take, as an example, the mode in which the Scotch housewife very generally prepares her barley-broth for the family. As an old song says, 'She makes a great fire, and she puts on the pot,' well filled with water, into which are put the meat and barley, mixed with pease. The water immediately gets into a violent state of ebullition, which is continued for two hours, two hours and a half, or longer, as time may permit. To prevent the cover of the pot being blown off, from the great quantity of steam generated, it is removed, or, more usually, the 'porridge-spurtle' is introduced, so as to keep the cover partially off, and allow the contents of the pot an easy escape. After this process has proceeded for an hour or so, the vegetables are introduced, and, as violent boiling implies diminution in quantity, 'ekes' of water are made at intervals, to keep the whole up to the required amount. Now, what we have to complain of here is, that with all the violent demonstrations which the pot has for hours been making, the result to the family is most unsatisfactory, for they obtain, at considerable cost, only a watery, tasteless compound, instead of a wholesome savoury mess. No doubt, it is 'satisfactory' to the housewife, while the pot is violently boiling, to hear and see that something is being done; but she should consider that to boil such pots fast requires a good deal of coals, for which a high price has to be paid, and that, with all her fast boiling, she never makes the water one degree hotter than when it *just boils*, without giving any 'demonstrations,' and that in consequence all this noise is useless. And further, she should consider that, when her husband gives her money to buy beef, he expects that she will, in cooking it, faithfully preserve to him its nice savoury qualities, and not first diffuse these in the water, and then send them up the chimney with the steam. If she will think of this matter for a little, she will see also that the vegetables in her broth are a 'little' hard, and that there is no good reason why they should not be put into the pot at the commencement of the process, and be allowed to remain there until they become soft and pleasant to the taste, and diffuse their sweet juices through the whole compound. The result of the whole, we have no doubt, will be, if she will just give heed to a few of our 'instructions' in this and other things, that she will soon save for herself the price of several new gowns, and will make the dinner-hour a pleasant one for her husband to think of. 'Well, then,' she will say, 'how do *you* make barley-broth?' Here is the way in which we proceed:

Mutton or Beef Broth.—Take two or three pounds of a neck of mutton, or the same quantity of the shin or hough of beef, or of the flank or nineholes of beef, and put it on the fire with one gallon and a half of water—adding a bit of washing-soda, of the size of a large nut, where the water is the least hard—two tea-cupfuls of barley, and the same of dried green pease. Take also a large Swedish turnip, or two or three smaller ones, two carrots, three leeks, a moderately sized savoy or cabbage, and clean well and mince small on a mincing-board, grating portions of the carrot and turnip, and reserving some for serving with the meat. Boil the whole very gently for three and a half hours. The cover should be

kept perfectly closed, and whenever the least steam is seen to escape, the pot should be removed a little from the fire. Without strict attention to this last direction, the broth never can be properly made. Where hough or beef is used, it should previously have lain in salt for three or four days, as this improves both the broth and the flavour of the meat. A quarter of an hour before the broth is ready, add a little minced parsley. Serve the meat with pieces of the carrot and turnip, and a little of the thin of the broth as sauce. 'Greens,' so much used by the working-classes in Scotland, impoverish the broth, and should not be used if better vegetables can be got. In families where broth is much used, and where it is convenient, a supply of Swedish turnips, carrots, and onions should be laid in at the commencement of winter; and with these, and a little parsley, delightful broth can always be made.

Sheep-head Broth is made in exactly the same way as the above, the boiling being continued for four and a half hours. The head should have a pound of the neck attached to it. In Scotland, this, along with the 'trotters,' is sent to the smith's, who singes the hair with a red-hot iron. The head should then be scraped and sawn open, the internal parts well cleaned, and the whole soaked all night in water. The head and trotters should be served with pieces of carrot and turnip, and some of the thin of the broth. To preserve the true flavour of this delightful dish, it is rather particular that the 'scraping process' should not be carried too far. Part of an ox's head, which has lain in salt for a few days, may be used in the same way.

Hotch-potch is made in the same way as barley-broth, omitting the barley, and using young green pease, Turkey beans scalded and skinned, carrot and turnip, lettuces, young onions, and parsley. A neck of mutton may be used, or lamb-ribs, cut up, and served with the soup.

It is of the most particular importance, in making the above and most other soups, that sufficient time be given for the extraction and diffusion in the fluid of the juices of the meat and vegetables. Four hours, and sometimes more, are required. As many workmen breakfast at nine and dine at one o'clock, the housewife must, as soon as breakfast is over, look active, and have everything in readiness when she intends making such soups. A good plan, to save both fuel and trouble, is, where the size of the family admits of it, to have a pot sufficiently large to make broth for two days, and to heat the broth slowly on the second day, and make a hash of the meat that remains, by first taking the meat from the bones, where there are any, and boiling the latter for an hour in a little water, with onions, pepper, and salt, and then adding the meat, cut in small pieces, along with a small quantity of flour, and heating the whole together. A little curry-powder, a cheap article, which should be more known than it is at the working-man's table, makes a delightful seasoning to such a hash, to pease-soup, potato-soup, and in other ways that will be mentioned. It can either be added while cooking, or used at the table. Many think such a hash improved by the addition of a little plain vinegar, or the vinegar off pickles, where a little mace has been used among the seasonings.

A great variety of *broths* may be made upon the same principle as the barley-broth, by using different kinds of vegetables, omitting the barley, and 'lithing' them with a little flour, potato-starch, or arrow-root, &c.; and the housewife should especially study *variety* in preparing her husband's dinners.

An excellent and *economical broth*, sufficient in quantity for even a large family, may be made by taking a pound of fattish mutton, cutting into small pieces, frying slightly with lard or dripping and making a brown gravy with flour; and then adding this, along with salt, pepper, and a little sugar to the water and vegetables, and gently boiling, as directed, for three and a half hours. The sugar makes a good addition to broths, especially at the end of the season, when the vegetables have lost much of their saccharine matter.

Leek Soup.—Take two or three pounds of the shin or hough of beef, put it on in a gallon of water, with salt, pepper, and a little sugar; and boil gently, with close cover, for two hours. Clean very well, and cut into small pieces one or two dozen of large leeks, and boil for other two hours. The hough should be served with melted butter, or a sauce made of onions stewed with a bit of butter and a little flour. This can be converted into the Scotch soup called '*cock-a-leekie*' by using in addition a fowl, and adding a few prunes shortly before it is ready.

Turnip Soup.—Use the same quantity of beef and water as in the last, with one large Swedish turnip, or two or three smaller ones, two or three onions, and pepper and salt. When the turnips and onions are boiled soft, mash them through a drainer, and boil the whole very gently, with closed cover, for four hours.

Ox-tail Soup.—Take two ox-tails, cut into pieces, and put into a gallon of water, with two or three onions, a grated carrot and turnip, pepper and salt; and boil very gently, with closed cover, for four hours. The ox-tails should be served with the same sauce as is mentioned under the head of 'Leek Soup.' Curry-powder makes a good *occasional* seasoning for the last three soups.

Potato Soup.—Put on a gallon and a half of water, with salt, a bit of washing-soda about the size of a large nut, a small breakfast-cupful of roast-beef, mutton, or lamb dripping, or two pounds of a neck of mutton or of pork, or roast-beef or pork-ham bones, or any odd trimmings of meat—it is best, however, when made with fresh roast-beef dripping—three or four large onions sliced, half a stone of potatoes, cut into small pieces; and boil with closed cover, very gently, for two or three hours. When half ready, add a grated carrot. This soup, if well made, should be quite soft and pulpy, and may be rubbed through a sieve if required. Curry-powder makes its best seasoning.

Pease Soup.—Take two or three pounds of a shin or hough of beef, and put into a gallon and a half of water, with a bit of washing-soda the size of a large nut, two pounds of split pease, a moderately sized carrot and turnip, two or three onions, and a little celery-seed tied in a bit of muslin. When the carrot and turnip are boiled soft, mash, and return them to the pot. Boil with closed cover, very gently, for four hours. When ready, strain through a sieve, and serve with hard toasted bread, cut into dice, and thrown into the soup in the tureen, so as to preserve its crispness. The hough should be served with the same sauce as is mentioned under 'Leek Soup.' This soup may be made with bones or trimmings, or roast-beef dripping, the liquor a ham or any meat has been boiled in, or even without any of these, by frying the bread in plenty of lard before cutting it into dice. Its best seasoning is curry-powder. Vinegar added before serving, or at table, in the proportion of about a tea-spoonful to each plateful of soup, is thought by many to improve its flavour, and certainly promotes its digestibility. It immediately somewhat thickens the soup, apparently by acting as boiling water does when poured on arrow-root; and it removes in a great measure one great objection which many have to this fine soup—namely, the formation by it of flatus in the stomach and bowels.

Kidney Soup.—Take a pair of kidneys, cut them into slices, wash in boiling water, and dry with a towel. Have the frying-pan ready, with hot lard or dripping, into which put the sliced kidneys, two handfuls of flour, a few onions, a dessert-spoonful of Jamaica pepper, and a little black pepper and salt. Stir with a spoon, and brown nicely. Cut into very small pieces; add this to a gallon of water, and grate into it half a carrot and the same size of turnip, and boil with closed cover very gently for four hours. If wished particularly good, a pound or so of hough of beef may be added;

but if plenty of dripping is used, this is not required. With less water and flour, and omitting the carrot and turnip, this makes a delightful stew.

Fish Soup, or '*Crappit Heads*.'—This favourite Scotch dish is made with two or three very fresh middle-sized haddocks. Clean well, cut off the heads, and cut the bodies into three pieces. Mince a few small onions and a little parsley, and mix with a large handful of Scotch oatmeal, a quarter of a pound of butter, a little pepper, and a very little salt. Work this into a paste without water, stuff the heads and the upper parts of the bodies with it, and tie firmly with a bit of thread. Put into four quarts of water, and boil gently for half an hour. If any of the paste is left over, it should be made into balls, and boiled along with the fish. Serve in a tureen, and eat with potatoes.

In hot summer weather, lighter soups than those that have been mentioned are grateful. A good one is

Veal Soup.—Take a good-sized knuckle of veal, and put it on in four quarts of water, with an onion or two; and when it has gently boiled an hour, add two tea-cupfuls of rice, and let it simmer for other two hours. A quarter of an hour before it is ready, add a little minced parsley. Serve the veal with melted butter and parsley.

In such weather, also, curdled milk, with or without cream, or rice and milk, make pleasant varieties. Cayenne or black pepper makes an agreeable seasoning for the curdled milk.

Rice and Milk.—Take a pound and a half of rice, and wash till the water runs clear from it. Put it on in as much water as will cover it an inch above the rice, with a little salt. Let it simmer very slowly with a closed cover, without stirring, for an hour and a half. When ready, add as much milk as may be wished, with a bit of butter, and let it just boil. Eat with sugar and a little curry-powder.

On the continent, in summer, thinner soups, such as the following ones, are much used:

Sour-milk Soup.—Take any quantity of sour-milk required, and boil with a few bits of lemon-peel and a little ground cinnamon. Prepare sufficient flour of rice with milk, to thicken it, and pour into the boiling sour-milk, stirring for a few minutes till ready. Sweeten with sugar or treacle, and add some grated almonds and raisins, according to taste.

Porridge Soup with Prunes.—Take a breakfast-cupful of oatmeal, and boil, with enough of water to make a soup, for an hour. A short time before serving, add treacle, vinegar, and cinnamon, according to taste.

Rice Soup.—Take a breakfast-cupful of whole rice, boil, with sufficient water, for an hour, and then add some ground cinnamon, and eight or ten drops of essence of lemon. It may be varied by boiling with the rice a few bits of lemon-peel, and by pouring the soup in the tureen on two or three eggs, beat up with a little sherry wine or rum, and stirring well. In this case, the butter is omitted.

Other soups of this kind are made with sago, potato-starch, &c., and flavoured with cranberry juice, raspberry vinegar, &c. The cranberries should be gathered at the proper season, and be preserved simply in water. In Norway, Denmark, &c., the juice is much used in soups, and the whole berries for tarts. They cost very little in these countries, and are frequently imported into this.

The Scotch working-man almost invariably takes his soup first, and eats afterwards a portion of the meat with which it has been made. When it is wished not to have the qualities of the meat too much diffused in the soup, it is sometimes taken out for an hour or so. Where mutton is used, instead of returning it to the soup, it may be sprinkled with a little pepper and salt, slightly browned before the fire, and served with an onion sauce, which is made by stewing a few onions in a little water for half an hour, and adding a little butter and flour. This greatly improves the qualities of the mutton. As has been already mentioned, when it is intended that the meat should be eaten without the soup, instead of using cold water, it should at once be immersed in boiling water, so as to coagulate the outer layer of albumen, and retain its juices; and then boil with closed cover very gently whatever time may be required, a quarter of an hour being allowed for each pound of meat. The water in which the meat has been boiled can be used next day as a stock for making broth or soup.

Roast Beef—for cooking which, see p. 759—is generally considered, in the working-man's house, an expensive dish; but when some kind of soup is used along with it, and account is taken of the dripping and bones, to be used in potato or pease soup, this may be doubted.

The following are good and economical forms of using beef, &c.:

Minced Collops.—Get a pound of steak minced very small, along with a bit of suet—in Scotland, the butcher usually does the mincing—put on in a stew-pan, with a good handful of flour, pepper, salt, and two tea-cupfuls of water. Have a wooden beater, and beat all the time they are cooking, to prevent lumps forming. They should be quickly made ready. As soon as they fairly boil all through, dish and serve them. Eat with vinegar and pickles.

Fried Beef-steak.—Take a pound of beef-steak, not too thickly cut, and beat well with the rolling-pin. Put a bit of dripping in the frying-pan, and brown the steak till ready with three or four sliced onions, and pepper and salt. When ready, put the steak and onions on the dish they are to be served on, and sprinkle a little flour in the pan, and brown it. Pour some cold water on this, with a little salt; bring to the boil, pour over the steak through a drainer, and serve hot.

Beef-olives.—Take a pound of beef-steak, and cut into three pieces, mince a little bit of suet with an onion or two; sprinkle this over the steak, with a little Jamaica pepper, black pepper, salt, and a little flour, and roll each piece up, and tie with a bit of thread. Put into a stew-pan, with a little water, a tea-spoonful of Jamaica pepper, a morsel of butter, a table-spoonful of flour, and stew slowly with closed cover for an hour and a half.

Beef à la Mode.—Take two or three pounds of hough or shin of beef; rub well with Jamaica pepper, black pepper, and salt; put on in a stew-pan with a very little water, a bit of fat bacon, a few sliced onions, carrot, and turnip; and stew very slowly with closed cover for four and a half hours. A quarter of an hour before serving, skim off the floating fat, and add a little browned flour and water.

Potato Pie.—Heat the oven, and make ready a panful of skinned potatoes. Put a pound of beef-steak into a pie-dish, with two or three sliced onions, pepper, salt, and a little water. Put a cover over this, and set it in the oven for half an hour. When the potatoes are ready, add a little milk and a bit of dripping, mash well, and cover the meat in the dish with them. If the oven is hot, the potatoes should be browned on the top and the meat ready in an hour. Before serving, add a small tea-cupful of hot water. Where there is not an oven, the Scotch 'girdle' may be used.

Beef-steak Dumpling.—Take a pound of beef-steak, and cut it into several pieces. Mix with one pound of flour a heaped tea-spoonful of Borwick's Baking-powder, add a quarter of a pound of lard, dripping, or minced suet, and make a paste with a small tea-cupful of water. Line a basin with this paste, and enclose the meat in thè dish with the same, adding three or four onions, pepper, and salt, and boil in a cloth for two and a half hours. While dishing, add a little hot water through a hole in the paste, and eat with potatoes. Mutton, veal, or lamb may also be similarly used.

Beef-steak, Pigeon, Crow, or *Veal Pie,* &c.—Take

three pounds beef-steak, beat it and roll in small pieces, previously sprinkling with Jamaica and black pepper, salt, and minced onions. Place in a pie-dish with some more sliced onions, pepper, and salt, and as much water as will fill the dish. Cover with a paste made as follows, which will also answer for tarts: Take a pound of flour, and mix with it a heaped tea-spoonful of Borwick's Baking-powder—a cheap article, which may be had at any druggist's—put in a bowl, and mix with this a quarter of a pound of lard, butter, or dripping, and rather more than half a tea-cupful of water. Stir round in the bowl with a spoon, and then roll over and over with the rolling-pin till smooth. Cut the paste out the size of the dish, roll out the parings, and cut them into strips. Wet the edges of the dish, and place these strips neatly round on the edges, as a foundation for the cover. Then, after putting in the meat, lay the cover on the dish, pressing down the edges closely to keep all tight. If any paste remain, cut or stamp it in ornaments—such as leaves—and place these as a decoration on the cover. Bake immediately in a hot oven for an hour and a half. Before serving, add a little boiling water for gravy.

Pigeon Pie is made in the same way, putting a pound of steak in the bottom of the dish, and seasoning only with black pepper and a very little onion. The pigeons must be cleaned well, a bit of butter rolled in pepper and salt put in each, and the gizzard, liver, and heart placed along with them.

Rook or *Crow Pie* is also made as above, putting a piece of fat bacon in each, and in the bottom of the dish, instead of the steak. The rooks—which should be young birds—have to be skinned, and care must be taken not to burst the gall-bladder in gutting them.

Veal Pie is made in the same way, with bacon, the seasonings being white pepper, salt, parsley, a little bit of onion, and a slice of lemon, keeping out the seeds of the latter and the end portions of the rind. *Chicken Pie* is made with the same seasonings.

Irish Stew.—Take a pound of neck of mutton, cut into small pieces, and brown with dripping in the frying-pan. Put into a stew-pan, with as much water as will cover the meat, plenty of onions, black pepper, and salt. While it is stewing slowly with closed cover, skin and slice as many potatoes as may be wanted, and place them over the meat. Close the cover, and stew for two hours very slowly, so as not to let the potatoes burn.

Stewed Veal.—Take two pounds of any fleshy part of veal, and cut into neat pieces. Have an egg beat up, and some bread-crumbs, with minced parsley, onions, white pepper, and salt, on a plate. Have some lard or dripping in the frying-pan. Dip the cut veal in the egg, and then in the crumbs, and fry till the veal is of a nice light brown. Put in a stew-pan with a little water, two tea-spoonfuls of flour, an onion, a little parsley, and two slices of lemon, and stew slowly with closed cover for an hour. Serve with some slices of lemon round the dish.

Curried Rabbit, &c.—Cut a rabbit into pieces, wash well, and put in a stew-pan with a quarter of a pound of butter, a dessert-spoonful of curry-powder, and three or four large onions, and as much water as will cover the meat. Stew slowly with closed cover for two hours. Half an hour before dishing, add a table-spoonful of flour moistened with cold water. Eat with potatoes, and rice prepared as follows: Take a breakfast-cupful of rice, wash till the water runs clear, and put on with just as much water as will cover it, adding a little salt. Let it simmer very slowly with closed cover, without stirring it, for an hour and a quarter. It should be quite dry when dished. Excellent curries may be made in the same way by using fowl or chicken, fish, ox-heart, or any cold meat. The fish and cold meat will be ready in half an hour; the ox-heart ought first to be parboiled, and requires two hours to make it ready. If the curry-powder is omitted, these dishes are all stews.

Salt Fish.—Cut the salt cod or ling into pieces, and soak in plenty of water for thirty-six hours. Put on in plenty of cold water, and let it simmer slowly with closed cover for three hours. Make a sauce of butter, flour, and water, with one or more hard-boiled eggs minced into it, and eat with mustard and potatoes. If there is any fish left, bone it next day, mix up with beat potatoes and a good bit of butter, and brown before the fire.

Oatmeal Pudding.—Take a pound of suet, mince with it six onions, and add this to a pound and a half of Scotch oatmeal, with pepper and a very little salt. Boil for three hours, and eat with potatoes. A little bit of parboiled liver, minced with bacon, may be added if wished.

White-skin Pudding.—The same ingredients, without the liver and bacon, may be used for making white-skin puddings. The small intestines of the ox or sheep are used, and must be particularly well cleaned, and not stuffed too full. They should be boiled very gently for half an hour, and hung up for use. Parboil and toast before the fire before eating.

Black Puddings.—Mince two pounds of suet, twelve onions, pepper, salt, and a little sage dried and rubbed into powder, and stir together with two handfuls of oatmeal and three imperial pints of ox's or pig's blood. Fill the skins as above, and boil slowly for half an hour. Hang up, and use as before.

Fried Liver.—Take a part of the portion called the 'tongue' of an ox's liver, parboil, cut into thin slices, and fry with sliced onions and fat bacon. Remove the liver and bacon, sprinkle a little flour in the pan, and brown it; pour on a little water, and bring to the boil as sauce. Lamb or sheep's liver should be cut in thin slices, but does not require to be parboiled.

Dressed Sheep's Pluck.—The pluck in Scotland includes the heart, lungs, and liver. Take a sheep's heart, lungs, and half of the liver, and parboil. Mince fine with two or three onions, parsley, pepper, and salt. Put in a stew-pan with a handful of flour and two tea-cupfuls of water. Stew slowly with closed cover for an hour and a half. Cut the other half of the liver into thin slices, fry with fat bacon, and serve round the stew.

Mutton Haricot.—Take a pound of mutton-chops, beat, and brown in the frying-pan with lard or dripping. When browned, put in a stew-pan, with just as much water as will cover the meat, pepper, salt, a sliced carrot, a turnip, and two or three onions. Stew slowly for an hour and a half, adding a dessert-spoonful of flour, moistened with a little water, a quarter of an hour before serving. These dishes, however well cooked, will yet lose half their relish if served in a slovenly manner, or allowed to get cold and out of season. Where the meats are hot, they should always be dished and served quickly, and especially always be eaten from heated plates.

From the directions which are to be found under their proper heads, the housewife will have no difficulty in now and then making nice additions to her dinner fare in the form of a pudding, a dumpling, or a tart. These, when properly managed, are wholesome dishes, and, where fruit is cheap, are not very expensive. For the tarts and pies, however, it is quite essential that the housewife have a good working oven; and we have shewn that there is no great difficulty in obtaining this. The materials for tarts most accessible are—in spring, the Victoria rhubarb, and, as the season advances, this mixed with gooseberries, or gooseberries alone. When the rhubarb has become old, it is generally little used, and is cheap. When, however, at this season it is mixed with blaeberries, or wild rasps, it makes a delicious tart. Currants, apples, and other fruits can be used when convenient. The wild rasp makes a delightful preserve for using in dumplings, and for eating with boiled rice and cream, or milk, &c. For

this purpose, making this and red gooseberry jam should be attended to at the proper season. Directions for making these will be found at page 765.

A very plain dinner is made delicious where there are plenty of tender, well-dressed vegetables, of which an abundance may easily be obtained where a workman possesses a little garden. Where he has done justice to his garden, and has applied liquid manure, guano, &c., thus causing the plants to rush quickly up, the commonest vegetable becomes a treat; for example, cabbages—often a coarse vegetable—either alone or beat up with potatoes and dripping, makes a delightful relish. During the summer, too, a small morsel of ground will give him the means of having a constant supply of delicious salads. He has only to tie with a bit of string the tops of his lettuces, and thus blanch them, and to mince them with young onions and a hard-boiled egg, mixing with vinegar and salt, to have, through the warm season, a salad which even a gourmand would not despise; while his young cresses and radishes form a relish for breakfast, dinner, tea, or supper.

Having spoken, as fully as our space will allow, of the more solid dishes a workman may command, we have only a few words to say as to some other matters. For *tea*, he can have, as a variety to his bread and butter, cakes of various kinds. *Soda scones*—done in the oven, or on the 'girdle' used in Scotland—are made by mixing with the flour a little carbonate of soda, salt, and churned milk, rather sour. If the milk should not be sufficiently sour, a little tartaric acid may be added, to quicken the effervescence from the soda. They can be made richer by adding a little lard or dripping. A very nice kind of domestic *crumpet* is made with the same materials, mixed just thin enough to pour, the girdle being previously made hot, and greased with lard. They are rather difficult to turn; but by loosening the edges, and using a broad knife, this can easily be managed with a little practice. They should be eaten hot with salt-butter. *Scotch oat-cakes* are eaten with relish, when well made, by all classes. Their excellence chiefly depends on their being short and crisp, which qualities are procured by adding to the water with which they are made, that little carbonate of soda, and firing them slowly, so as they shall be thoroughly done; and when a few days old, they should be again slightly heated, to bring back their crispness. When they are wanted richer and very crisp, a little lard or lamb-dripping may be used, and the soda omitted.

For *supper*, a bit of cheese, a little porridge, a salad, a hard-boiled egg with pickles, milk in some form, &c., will be taken according to taste.

Curried Milk.—In cold weather, a wholesome and very palatable form of using milk is as follows: Boil the milk, and add a little salt, sugar, and curry-powder. Use this with bread cut thin and toasted hard, cut in small pieces.

Pease Brose is a favourite supper with some in Scotland. It is made with the Glasgow brose-meal as follows: Put as much meal as is required in a bowl, with a little salt, and stir boiling water into it, making it of a thick consistency. Eat with sweet or butter milk.

Killing a pig gives the means, to a cottager's or workman's family, of having several nice luxuries, such as the blood and white puddings, the dressed 'pluck,' the salted 'pig's cheek,' eaten with greens, the feet salted slightly, and made into delicate soup with vegetables, tasty pork-sausages, rich pork and mince pie, and delicious spare-rib roasted. The suet should be carefully 'rinded' by melting off the lard in a pot placed in boiling water, adding a little salt, and then should be put in pots covered with bladder, or in bladders, to exclude the air. It may be used, when required for pie-crust, &c.

Pork Sausages are made by mincing the fat and lean pork, seasoning with black and Jamaica ground pepper, dry sage rubbed down, and half filling the intestines —well cleaned—and frying.

The *Spare-rib* is a favourite part of the pork for roasting in England. A good bit of the lean meat is left on when the flesh is cut away. This mode of cutting should be adopted in Scotland.

Pork Pies are much made in England, and are greatly relished when eaten cold. Take any spare pieces of pork, mixed lean and fat, cut into small pieces, and flavour with dried sage, rubbed down—a little ground mace is sometimes added—black and Cayenne pepper, and salt. Enclose in a paste, as described under head 'Beef-steak Pie,' of the same shape as the small mutton pies, but of any size wished; add a little water, bake in a not too hot oven for two hours or so, according to size, and eat when cold. The same meat, &c., can be made into a dumpling, as described under head 'Beef-steak Dumpling,' and eaten hot.

ROASTING.

Meat is roasted by being exposed to the direct influence of fire. This is done by placing the meat before a fire, and keeping it constantly in motion, to prevent scorching on any particular part.

Dripping.—Roast-beef yields a dripping, which is a valuable article in the economy of the kitchen. It should be removed from the pan beneath the meat before it becomes overheated, or scorched by the fire, leaving sufficient for basting. Dripping is prepared for future use in the following manner: Take it hot from the dripping-pan and pour it into boiling water, that all particles of cinder or other improper matter may fall to the bottom, and leave the pure fat on the surface. Collect these cakes of fat, and by heating them in a jar, placed in a sauce-pan of boiling water, the whole will become a solid mass, and may be thus put aside for use. This process not only purifies dripping, but gives it a clear white colour.

To roast Beef.—The best piece of beef for roasting is the sirloin. If the suet be not required, it may be ordered to be cut off before purchasing the joint; a small piece of suet is all that is requisite for the purpose of basting. If at all musty, it should be washed with salt and water, and wiped quite dry. Hang it on the hook of the jack, in the way most advantageous for being operated upon uniformly by the fire. Handle it as little as possible. The fire must be quite clear and brisk. It is customary to allow a quarter of an hour for every pound of the meat. While roasting, baste it very frequently with its own dripping. In dishing, pour a little boiling water and salt over it for a gravy. A well-roasted joint ought to have a nice rich brown tinge, and this is to be obtained only by careful basting, attention to the fire, and removing at the proper time, when experience tells that the joint is 'done.' Garnish with scraped horse-radish.

To roast Mutton.—The best parts of mutton for roasting are the leg, the shoulder, and the loin. The piece may be kept longer than would be desirable for mutton for boiling. It should have a clear and brisk fire. A leg will take two hours to roast; but this, as well as the time for roasting the other parts, must be regulated by the fire and the weight of the meat, and can be learned only by attention. The joint of mutton should be basted the same as beef, with its own dripping, and a gravy should be made for it as above.

To roast Venison.—Venison is roasted in the same manner as mutton, but requires longer time at the fire. It is such a dry meat, and the fat is so easily melted, that it should be covered with buttered paper, and well basted. Serve with a good gravy and currant-jelly.

To roast Veal.—The best parts of veal for roasting are the fillet, the breast, the loin, and the shoulder. The fillet and the breast should be stuffed, particularly

the fillet, with a composition of crumbs of bread, chopped suet and parsley, a little lemon-peel, and pepper and salt, wet with an egg and a little milk. Let it be well basted with butter when there is not sufficient dripping from the joint. The gravy for roast veal is either the usual hot water and salt, or thin melted butter, poured over the meat.

To roast Lamb.—Lamb also requires to be well roasted. It is usually dressed in quarters; all parts, particularly the spinal bone, should be well jointed or cut by the butcher or cook; and the ribs of the fore-quarter broken across the centre, in order to accommodate the carver. In roasting, baste, as already described, with its own dripping. The gravy for lamb may be the same as for beef or mutton—namely, hot water and salt poured over it. A very nice stuffing for lamb is often used in Scotland: mince some of the suet, an onion, and a few blades of parsley, and mix with a handful of oatmeal, a little pepper, and a very little salt. Make a hole in the loose skin of the loin, fill with the above, and sew up. Eat with the lamb, and mint-sauce.

To roast Pork.—Pork requires a longer time in roasting than any of the preceding meats. When stuffing is to be used, it must be composed of chopped sage and onion, pepper and salt. The pieces should be neatly and well scored in regular stripes on the outer skin, to enable the carver to cut slices easily. Before putting to the fire, rub the skin with salad-oil, to prevent its blistering, and baste very frequently. The basting may be done by rubbing it with a piece of butter in a muslin bag, where there is not enough of dripping. The gravy for pork may be the same as for other joints, hot water and salt poured over it on the dish. It is considered an improvement to have apple-sauce served in a small tureen, as it assists in overcoming the richness or lusciousness of the meat, and imparts an agreeable acidulous flavour.

To roast Bullock's Heart.—Wash the heart well, freeing it completely from blood. Then fill all the openings at the top or broad end with a stuffing composed of crumbs of bread, chopped suet, parsley, pepper and salt, moistened with an egg and a little milk. Suspend with the pointed end downwards. An hour and a half, or two hours, according to the degree of heat, will cook the dish. It should, however, be well done. Send to table with beef-gravy.

To roast Fowls.—Pick, draw, and singe them. A fowl should be so cleanly or well drawn as to require no washing. Take care not to break the gall-bag in drawing; if the gall be spilled, it will communicate a bitter taste to every part it touches. Press down the breast-bone. Break the legs by the middle of the first joint, drawing out the sinews, and cutting off the parts at the break. It being proper that roast fowls should have a neat appearance at table, it is customary to *truss* them—that is, to fix their legs and wings in a particular position. This is done by fixing down the knees of the animal close to the tail by a skewer or piece of string, leaving the stumps of the legs projecting. The pinion ends of the wings are then turned round on the back, the liver being placed as an ornament in one wing, and the gizzard in the other. Cut the head off close to the body, leaving a sufficiency of the skin to be tied or skewered on the back. Baste well with butter for some time after putting to the fire. Suspend neck downwards. The time of roasting will vary from half an hour to an hour, according to the size of the chicken or fowl. When a fowl is large, it is frequently stuffed like a turkey. Serve roast fowls with melted butter or a sauce made of the neck, the liver chopped, a little butter and flour. Before sending to table, remove all skewers and strings which may have been used in trussing. This, which should be done in all cases of serving dishes to table, is too frequently neglected, and shews slovenliness in cookery. Fowls, and all other feathered animals, are served with the breast upwards.

To roast Turkey.—Pick, draw, and singe the turkey well. Press down the breast-bone, and follow all the directions given for trussing fowls. The breast should be stuffed with crumbs of bread, minced beef-suet or marrow, minced parsley, a little nutmeg, pepper, and salt; wet it with milk and egg; a little sausage-meat may also be added. On finishing, sew up the orifice or neck. Before putting to the fire, cover the breast with a sheet of writing-paper well buttered, to preserve it from scorching, and which may be removed a short time before taking from the fire, to allow the breast to be browned. Baste well with butter. A turkey will take from an hour and a half to two hours. Serve with gravy-sauce.

To roast Pigeons.—Pick and draw them well, and truss, keeping on the feet. Make a stuffing of the liver chopped, crumbs of bread, minced parsley, pepper, salt, and a little butter; put this inside. Make a slit in one of the legs, and slip the other leg through it. Skewer and roast them for half an hour, basting them well with butter. Serve with beef-gravy in a small tureen, and on toast-bread placed under them while roasting, to catch 'the trail.'

To roast Partridges and other Game.—Pick, draw, singe, and clean these birds the same as fowls. Leave the head on, make a slit in the neck, and draw out the craw. Twist the neck round the wing, and bring the head round to the side of the breast. The legs and wings may be trussed in much the same manner as fowls. The feet are left on, and crossed over one into the other, as seen in the annexed figure. Baste well with butter before a clear fire. When about half done, dust a little flour over them to be browned. A partridge will take from twenty minutes to half an hour, and a pheasant three-quarters of an hour. Serve on toasted bread, with gravy, as above. Grouse and black-cock should be dressed and served in the same manner; the head being trussed under the wing. Snipes and woodcocks are not drawn.

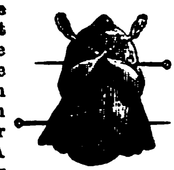


Fig. 3.

To roast Goose.—Pick, draw, and singe the goose well. Cut off its head and neck. Take off the legs and wings at the first joint. The portions of the legs and wings that are left are skewered to the sides. Stuff with chopped sage and onion, and crumbs of bread, with pepper and salt. The skin of the neck must be tied securely, to prevent the gravy from running out. Paper the breast for a short time. A goose does not require so much basting as fowl or turkey, for it is naturally greasy. It will require from two hours to two hours and a half in roasting. It ought to be thoroughly done. Serve with gravy-sauce and apple-sauce. The liver, gizzard, head, neck, feet, scalded and skinned, and the pinions of the goose, form what is termed the *giblets*, and compose a good stew or pie. The blood of the goose makes a good blood-pudding, using bread-crumbs instead of oatmeal, as directed, p. 758. It can be done before the fire, or in the oven. Sometimes it is included in the skin of the neck cut off, and tied at both ends, and is baked in the giblet-pie.

To roast Ducks.—Pick, draw, and singe them well. Take off their heads. Dip their feet in boiling water, to take off the outer yellow skin. Truss them neatly, turning the feet flat upon the back. Stuff as in the case of goose, and serve with the same sauces. A duck requires about an hour in roasting.

To roast Hare.—A hare will keep with the skin on it, and paunched, for two or three weeks in cold weather. It is then fit for roasting. First cut off the feet, and commence drawing off the skin at the hind-legs, proceeding along the body to the head. Be careful not to tear the ears in skinning them. Soak and wash well in several waters, and then wipe quite dry. Stuff with

crumbs of bread, chopped parsley, a bit of beef or veal suet chopped finely, a little grated lemon-peel and nutmeg, a piece of liver boiled and finely chopped or grated, and pepper and salt; the whole moistened with an egg,

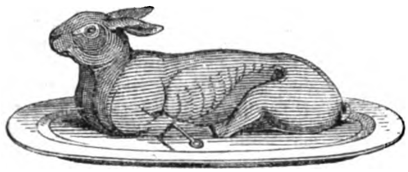


Fig. 4.

a little milk, and a spoonful of ketchup. The skin of the belly afterwards to be sewed. Commence trussing, by placing the hind and fore legs flat against the sides. To make the hind legs lie flat, the under sinews must be cut. Fix the head between the two shoulders, on the back, by running a skewer through it into the body. In roasting, suspend head downwards. It should be basted first with milk, afterwards with butter, flouring it lightly. It will require from an hour and a half to two hours. The hare is dished back upwards, as represented above, and served with a dish of rich beef-gravy, and a dish of currant-jelly.

BAKING.

Meat is prepared for baking in the same manner as for roasting. It should be placed in a deep dish for receiving the fat which flows from it; not laid, however, on the sole of the dish, but raised on a stand, to prevent the grease soaking into it. Small iron stands are made and sold for this purpose. Few dishes are so good when baked as when roasted, the meat being so liable to be shrivelled for lack of basting; and being liable, moreover, if done in a baker's oven, to partake of the flavour of the multifarious articles which are there prepared. Perhaps the only dishes which are better baked than roasted, are bullock's heart and leg of pork, because in roasting they are liable to be scorched on the outside before they are thoroughly cooked in the inner parts. In baking a heart, place it in a stand in a dish with the point downwards; a piece of writing-paper, buttered, may be placed over it, to keep the stuffing from drying. The sauce used is beef-gravy.

BROILING.

Broiling is the rapid cooking of any kind of animal food by the influence of fire. The apparatus required in broiling is very simple, and consists only of a gridiron, whose bars should be small bars, and kept thoroughly clean, not only on the tops, but on the sides. An improved form of gridiron consists of channeled bars leading to a trough or receptacle for the exuded juices. Let the iron be heated for a few minutes before placing the meat upon it; and rub the warm bars with a piece of brown paper, to prevent the meat from sticking to them. The operation of broiling requires a clear strong fire, with no smoke. In almost all cases, the meat ought to be frequently turned, which may be best done by a pair of small tongs; a fork should on no account be used in turning, for it breaks the skin of the meat, and allows the gravy to run out. Broiling possesses the peculiarity of being applicable only to meat which is to be eaten immediately on being dressed. This is an advantage when expeditious cooking is required, but a disadvantage when there is any uncertainty as to the time at which the meat is to be eaten. It is by no means an economical method, as a great proportion of the nutritious juices is discharged from the flesh beyond the means of recovery.

To broil Beef-steak.—A beef-steak is the most suitable of all kinds of meat for broiling, and is a dish universally relished. There are several parts of beef used for steaks, but in no case should it be from an animal too newly killed. The best steak is that cut from the rump—called in Scotland the *heuk-bone*—because it is the most juicy and well flavoured. Steaks should be cut in slices of from three-quarters of an inch to an inch in thickness, and into pieces of a convenient size for turning. Some persons dust the steaks with pepper before putting them to the fire, by which means the flavour of the pepper is infused through the mass. When placed on the gridiron, turn them very frequently; it is said, indeed, that the steaks should never be at rest, but this is carrying matters to an extremity. It is impossible to state any exact length of time to be employed in cooking a steak, for much depends on the tenderness and thickness of the meat, and the strength of the fire. The taste of the individual who is to eat the steak must also regulate the length of time; because, while some prefer steaks in a half-raw state, others wish them to be well done, that is, to have the colouring matter of the blood fully coagulated. When cooked to the extent which is required, place the steak on a hot dish, and after rubbing it with a little good fresh butter, sprinkle it with a little fine salt. Beef-steaks should be carried to table immediately on being dressed, and eaten forthwith, in order to be in perfection. Every moment they stand, they lose a portion of their flavour and juice. When sauce is required, either ketchup or oyster sauce may be used.

To broil Mutton-chops.—Mutton-chops should be cut from the middle of the hind loin, and about the same thickness as steaks. They are broiled in the same manner as steaks, and require equal attention. No butter is to be used on dishing, as the chop is sufficiently fat of itself. Sprinkle a little salt on it, and carry to the table immediately. Ketchup may be used as an adjunct.

FRYING.

Frying is as expeditious a mode of cooking as broiling, requires less activity and care, and is more thrifty. The thriftiness of frying is a point of material consequence, and may be thus explained. It affords a ready means of dressing in a savoury manner many odd pieces of uncooked or cold meat, thereby saving that which might otherwise have been thrown away as useless. A skilful housewife, with the aid of a frying-pan and some cheap vegetables, such as onions and potatoes, along with a slight seasoning, will make a small portion of meat dine a large family. A frying-pan should be of malleable, not of cast iron. It should also be thick in the bottom, and of an oval form. It should always be kept clean, by being washed with boiling water, but not scoured. In using it, a small piece of dripping, butter, or lard, must be put into it, and melted, to prevent the meat from adhering to it. In frying all meats, excepting those which are sufficiently fat in themselves, it is necessary to use some kind of grease or fat. The best fat for this purpose is lard, which is more economical, and less likely to get burned than butter. When lard is not employed, the best substitute for it is dripping.

To fry Mutton-chops.—They require to be cut in the same manner as for broiling, and may be dressed according to the directions for steaks, &c. None of the grease which flows from the chops is to be used along with them, and the whole must be poured away before preparing the gravy.

To fry Veal Cutlets.—Veal cutlets form a delicate dish, and should be fried with butter. The best cutlets are from the fillet, because they are free from bone; the fore or hind loin—that is, the back-ribs or loin—may be used, but the bone must be cut away, which causes a waste. Cut them half an inch in thickness. They require to be dressed slowly and thoroughly, and should be of a light-brown tinge when finished.—Another and more tasteful way of dressing cutlets, is to dip

them in a beat egg, strew them with crumbs of bread, and parsley chopped very fine, along with pepper and salt, and then put them in the pan. They will require more lard or dripping this way than when fried plain. Gravy may be made for cutlets the same as for fried steaks, but add a little juice of a lemon, and skim the gravy before pouring it over the cutlets. Serve with slices of lemon.

To fry Lamb-chops.—Lamb-chops may be either simply fried in the same manner as mutton-chops, or dressed with egg and crumbs of bread (but with no parsley), as in the case of cutlets. Gravy made in the pan, as for fried steaks.

To fry Pork-chops.—Pork-chops should be cut rather thin, and be thoroughly dressed. They may be either simply fried in the same manner as chops, or fried after being dipped in egg, and sprinkled with crumbs of bread, and sage and onion finely chopped. No gravy is expected with pork-chops. If any sauce be used, it must be apple-sauce.

To fry Beef or Pork Sausages.—All sausages are fried alike, and require to be dressed very slowly. Before being put into the pan, they should be pricked in several places with a fine fork, to prevent their bursting by the expansion of the air within. It is common in England to bring fried sausages to table neatly laid out on a flat dish of mashed potatoes. The sausages and potatoes are helped together. They may also be laid in links on toasted bread, and garnished with poached eggs round the dish. Fried sausages are sometimes used for garnishing roast turkey.

To fry Tripe.—The tripe must be washed well, and boiled till tender. Take the thickest parts, and dry them well with a cloth. Make a thick batter of egg, flour, and milk, seasoned with salt, and for those who wish it, a little minced onion. Dip the tripe into the batter so formed, after which fry in lard or good fresh dripping, of which there must be a sufficiency in the pan almost to cover the tripe. Let it be done to a light-brown. Garnish with fried parsley.

To fry Bacon, or Ham and Eggs.—The bacon should be cut in slices about an eighth of an inch in thickness. The best bacon is that which is alternately streaked with fat and lean. No butter or dripping is required in the pan in frying bacon, which does not need much dressing, and is soon prepared. When done, take the slices from the pan, and place them in a hot dish before the fire. Have the number of eggs required previously broken, each in a separate cup, and place them gently in the pan, so as to preserve them in a round flat shape. Let them remain in the pan till the white is set, and take them out carefully with a slice, and place them on the bacon. The tasteful appearance of this dish is spoiled if the eggs be either broken or ragged, which is very apt to be the case if they are not previously put into cups.

BOILING.

Boiling is the preparation of meat in water, and it is necessary that the vessel employed be large enough to allow the meat perfect freedom; if it be cramped, and have only a little water, it will be stewed, not boiled. In all cases of boiling, there must be a sufficiency of water to cover the meat. In boiling meat, there is less waste than in roasting; and in most cases, soup may be made of the liquor. As has already been remarked, the general direction to be attended to in boiling meat is, that where soup is to be made, the meat must be put into *cold* water, and very gently boiled; but when the chief object is to get the meat for eating, it is at once to be immersed in *boiling* water, and also very gently boiled—in both cases, with a closed cover.

When meat of any kind is done, and has to be lifted from the pot, take care not to put a fork into any part where there are juices; if this be not attended to, a portion of the juices will escape, and the marks of the fork will produce an unsightly appearance in the meat. All parts of mutton and lamb may be roasted, but it is only the leg, neck, and head that are boiled.

To boil a salted Round of Beef.—If large, cut out the bone, roll it up firmly, and bind it with a tape; then put it into the pot, and keep the lid close. Boil it slowly and equally, allowing a quarter of an hour for each pound of the beef. The appropriate garnishing for this and other pieces of boiled salt beef, is carrot and small greens; some add turnips. Put a little of the liquor in which it has been boiled in the dish.

To boil a Leg of Mutton.—A leg of mutton should be kept four or five days before boiling. Before putting it into the pot, bend round the shank, cutting the tendon at the joint, if necessary, so as to shorten the leg. Two hours of slow equal boiling will be sufficient for a good-sized leg of mutton. Some persons, to make the leg look white and tasteful, wrap it tightly in a cloth in boiling; but this spoils the liquor for broth. It is not safe to boil vegetables with a leg of mutton, as they are apt to flavour the meat. Dish the leg with a little of the liquor, placing the lower side uppermost, conveniently for carving. A good leg of mutton will soon yield sufficient gravy. For sauce, use finely chopped capers in melted butter, or the latter with pickled walnuts. Turnips mashed or whole form the appropriate vegetable to be eaten with this dish.

To boil Veal.—Veal is seldom boiled, being too insipid by that mode of dressing. The only part boiled is the knuckle, which requires much boiling, in order to soften the sinews. It is eaten with boiled ham or bacon. The sauce used is parsley and butter. The liquor from veal is the best of any for making soup.

To boil a Turkey.—Boiled turkey is one of the most delicate and excellent dishes which can be brought to table, and should be dressed with as much care as possible. Clean the turkey from all feathers, and singe the hair with burning paper, being careful not to blacken the skin. Clean it well inside by drawing and wiping. Cut off the legs at the first joints, and draw out the sinews; then pull down the skin, and push the legs inside. Cut off the head close to the body, leaving the skin long, and draw out the craw. Make a stuffing of chopped suet, crumbs of bread, chopped parsley, pepper, salt, and a little nutmeg, which wet with an egg and milk. Put this stuffing into the breast, leaving room for the stuffing to swell; after which draw the skin of the breast over the opening, and sew it neatly across the back; by which means, when the turkey is brought to table with its breast uppermost, no sewing will be seen. Place the liver in one wing, and the gizzard in the other, turning the wing on the back, and fixing the wings to the sides with a skewer. The turkey being now ready for the pot, put it into a cloth, and boil it for a length of time according to the size and age. A small young turkey will not require more than an hour and a half; an old and larger one, perhaps two and a half or three hours. Let the water be boiling in putting in, and of sufficient quantity to keep the turkey always covered. When done, and placed in a hot dish, pour a little sauce over the breast, and put the remainder in a sauce tureen. The sauce used is various—as parsley and butter, celery, or oyster sauce. One of the most delicate and agreeable sauces is that which is made of melted butter, boiled macaroni, and milk.

To boil a Fowl.—A fowl is to be prepared for boiling in the same manner as a turkey, except that no stuffing is used. It may be boiled with or without a cloth. Small fowls will require from half an hour to three-quarters of an hour; large fowls will require from an hour to an hour and a half. Sauce, parsley and butter.

To boil Rabbits whole.—Wash them well in warm water. They may be either stuffed or not stuffed, according to taste. When stuffing is required, make it of crumbs of bread, suet, parsley, and onions—all chopped—and pepper and salt; moisten with milk and

egg. Sew this neatly into the belly. Truss in the same manner as roast hare, and boil slowly for an hour. The sauce to be made of boiled onions, milk, melted butter, and flour, with pepper and salt, which pour over the rabbits when dished. This is called *rabbits smothered in onions.* When two rabbits are dished together, always lay the head of one in a contrary direction to that of the other.

To boil a Ham.—If the ham has been cured long, it may require soaking in cold water to soften it, from twelve to twenty-four hours before dressing. Put it in a large boiling vessel, with plenty of cold water, and let it simmer slowly from two to four hours, according to the size. Skim it frequently, to remove the grease which is constantly rising to the top. When done, skin it, and strew bread-raspings over the upper side; then place it before the fire to dry and brown. Garnish with greens or cabbage.

To boil Leg of Pork.—Pork requires to be particularly well boiled. Place it in the pot with the skin-side uppermost, with a plate below it, for pork is very apt to stick to the bottom of the pot. Pease-pudding is generally served separately with this dish.

To boil a Tongue.—If hard, soak the tongue in water all night before using. Boil it from two hours and a half to three hours. Skin it before dishing. Garnish with greens or spinage.

To boil Tripe.—When tripe is purchased from the butcher in a raw state, it requires to be boiled a very long time, to be thoroughly soft and tender. The length of time will depend on the age of the animal from which it has been taken. Sometimes, for young tripe, six or seven hours will be sufficient, while old tripe will perhaps take ten or twelve. In all cases, boil, or rather simmer it very slowly, for quick boiling hardens it. It should be cut into moderately sized pieces for helping at table. When to be served plain, carry to table in a hash-dish, in some of the water with which it has been boiled, with boiled onions in it. A tasteful way of serving is to take it from its liquor after boiling, and stew it for about ten minutes in a sauce-pan with milk, which thicken with a little arrow-root, or flour and butter, and season with pepper and salt, immediately before dishing, as otherwise the salt is apt to curdle the milk. This makes a delicious and cheap dish.

To boil Cow-heel.—Cow-heel should be boiled for five or six hours, or till the bones will slip out. Serve with a sauce of chopped parsley and butter.

To boil Eggs.—The boiling of eggs is a very simple operation, but is frequently ill performed. Put the egg gently into a pan of hot water just off the boil, and boil for three minutes or more, if the egg be quite fresh; or two minutes and a half, if the egg has been kept any time.

STEWS, HASHES, AND MADE DISHES.

Stewing is the preparing of meat by slow simmering or boiling, all the liquor being used along with the meat at table. This is a much more savoury and nutritious mode of cookery than boiling, because the substance of the meat is partly in the liquor, and is seasoned to have a high relish or flavour. Generally, much more can be made of meat by stewing than by roasting, boiling, or frying, because nothing is lost in the process of dressing. It also possesses the decided advantage of being a way by which meat may be dressed for a person whose time of dining is uncertain. A stewed steak, for instance, will keep warm and in good condition for an hour, but a broiled or fried steak cannot keep a minute after dressing.

To stew a Piece of Beef, or make Beef Bouilli.—Take a piece of beef—the brisket or rump, or any other piece that will become tender. Put a little butter in the bottom of the stew-pan, and then putting in the meat, partially fry or brown it all over. Then take it out, and lay two or three skewers in the bottom of the pan; after which replace the meat, which will be prevented from sticking to the pan by means of the skewers. Next, put in as much water as will half cover the meat. Stew it slowly, with the pan closely covered, till done, with a few onions if required. Two hours are considered enough for a piece of six or eight pounds. When ready, take out the meat, and thicken the gravy with a little butter and flour. Cut down into handsome shapes a boiled carrot and turnip, and add them to the liquor; season with pepper, salt, and ketchup. Boil all together for a few minutes, and serve in a hash-dish.

To dress Cold Boiled Beef, or make Bubble and Squeak.—Cut the beef in slices of about the third of an inch in thickness. Fry the slices till lightly browned and heated through. Then take them from the pan, and place them on a warm plate before the fire, to keep hot. Fry some cabbage which has been previously boiled and chopped; stir this about a short time in the pan, and season with pepper and salt. Spread the cabbage in a dish, and place the slices of meat upon it; or heap the cabbage in the dish, and place the meat around it.

To mince Cold Veal.—Cut the veal from the bones, and mince it in small square bits, and lay them aside. Then put the bones in a stew-pan with a little warm water, to make a gravy. After stewing for a short time, take out the bones and put in the bits of veal, with a small piece of lemon-peel, chopped very fine. When perfectly heated, thicken with a little flour and butter, and season with pepper and salt, and a little lemon-juice. Dish with small pieces of toasted bread, placed round the edge of the dish.

To dress a Lamb's Head and Pluck.—Lambs' heads are procured skinned. Take the head with the neck attached; split up the forehead, and take out the brains, which lay aside. Wash the head carefully, cleaning out the slime from the nose by rubbing it with salt, and take out the eyes. The head being thus cleaned, put it on to boil, along with the heart, and the lungs or lights. Let the whole boil for an hour and a quarter; then take them out, and dry the head and neck with a cloth. Rub it over with an egg well beaten; strew crumbs of bread, pepper, and salt over it; also stick small pieces of butter over it, and lay it in a dish before a clear fire, to be browned lightly. Mince the lungs and heart, and part of the liver, with some onion, parsley, pepper, salt, a little flour, and a table-spoonful of ketchup; mix all together, and add some of the liquor in which the head was boiled to form a gravy; let it simmer by the side of the fire for half an hour. Take the brains and beat them well with two eggs, two table-spoonfuls of flour, and a sprig of fine chopped parsley, also a little pepper and salt, and two or three table-spoonfuls of milk—the whole forming a batter. Have a frying-pan with a little lard or dripping, and fry the batter in small round cakes, which turn and brown lightly on both sides. Cut the remainder of the liver in slices, and dust it with flour, and fry it. Now lay the head upon a dish; place the hash round it, and lay a slice of liver and a brain-cake alternately on the hash all round. This forms a handsome and a savoury dish, but requires great attention on the part of the cook, to have all the various parts hot and equally ready at the time of dishing.

To make Potted-head.—This is a dish to be eaten cold as a jelly. Take the half of a bullock's head, and clean it; soak it in warm water, with a cow-heel, for two or three hours. Then boil very slowly with closed cover for eight or ten hours. When done, cut them in small pieces, and lay them aside; after which strain the liquor in which they have been boiled, and let it stand till it is cold, so that the fat may be easily skimmed. Put the whole into a sauce-pan, and boil for half an hour, and season with pepper and salt according to taste. Pour it into basins, or tin or earthenware shapes, which stand in a cool place. When quite cold, it forms a

jelly, and is ready for being turned out on a dish for use. If it do not come out easily, dip the basin or shape in hot water, and the heat will immediately loosen it. Garnish with sprigs of fresh parsley.

Potted-beef.—Take a hough or shin of beef, cut in pieces, and put in a brown can, and fully cover with water. Put a plate over the can, and closely tie down with paper, and stew gently all night by the side of the fire, or in a cool oven. In the morning, pour off the liquid into a brown plate, cut up the pieces of meat, and pound well in a mortar with black pepper, salt, and a little ground mace, Jamaica pepper, or cloves. Take a little of the gravy from under the fat, and mix well with the pounded beef. Put in jelly-cans or small pie-dishes, and place in the oven or on the girdle, and bring gently to the boil. Set aside until cool, and then run over the top of each a little butter melted, or a little of the fat from the beef—the first is the better—to exclude the air. Set aside in a cool place, where it may be kept fresh for months. Remove the fat from the remaining gravy, and use for pie-crusts, &c. The gravy itself can be used as an excellent stock for any soup. A very nice supper dish can be made by taking a little cold veal and cold ham, cutting into small dice, with two hard-boiled eggs cut in slices, putting these in a dish, and pouring on them a little of the gravy to form a jelly. Warm in the oven in a shape, and turn out when cold.

SOUPS, ETC.

Soups are the substance of meat infused in water by boiling, and are of many different kinds, but may be divided into two classes—namely, *brown* and *white*. The basis of brown soups is always beef, while the basis of white soups is generally veal.

Liebig's Beef-tea or Brown Soup.—The following plan is that proposed by Baron Liebig for obtaining a soup which shall contain the whole, or nearly the whole, of the nutritious elements of the flesh employed: 'When one pound of lean beef, free of fat and separated from the bones, in the finely chopped state in which it is used for beef-sausages or mince-meat, is uniformly mixed with its own weight of cold water, slowly heated to boiling, and the liquid, after boiling briskly for a minute or two, is strained through a cloth or sieve from the coagulated albumen and the fibrin, now become hard and horny, we obtain an equal weight of the most aromatic soup, of such strength as can be obtained even by boiling for hours from a piece of flesh. When mixed with salt, and the other usual additions by which soup is usually seasoned, and tinged somewhat darker by means of roasted onions or burnt sugar, it forms the very best soup that can be prepared from one pound of flesh.'

Hare Soup.—Take a fresh hare, and, when skinned, wipe it well with a cloth. Cut it open, and take out the entrails, taking great care not to lose any of the blood. Then cut the body into separate pieces, and put them in a pot with two or three quarts of water, along with any blood that may have run out. Put into the pot also two or three pounds of beef, previously browned in a stew-pan, and cut into pieces, likewise a sliced carrot, turnip, and onion, two sticks of celery, a few sprigs of thyme, a few Jamaica peppercorns, a few cloves, and four table-spoonfuls of flour mixed with cold water. Keep stirring till it boil, and let it boil for an hour and a half. When this is done, take the best pieces of the hare, which are the back and upper joints of the hind-legs. Lay these aside. Let the soup boil for other two hours. Then take out the remainder of the meat, and cut it off the bones, and pound it in a mortar, or otherwise mash it well. Put the meat thus pounded back into the soup, and strain the whole through a hair-sieve. Put the soup so purified into the pot, along with the best pieces of the hare which were laid aside, also two table-spoonfuls of ketchup. Boil this for half an hour; then add pepper and salt, and serve with the pieces of hare in the tureen.

Mock-turtle Soup.—This is made with a calf's head. It is best to get the head ready scraped and cleaned from the butcher, but with the skin on. If it be got in an uncleaned state, wash it, and put it into a pot with cold water, and boil it for a short time till the hair is loosened. Then scrape off the hair, split the head, clean it thoroughly, and take out the brains. The head is now supposed to be clean, and ready for making the soup. Put it into a pot with considerably more water than will cover it. Skim it frequently as it warms, and let it boil gently for an hour. Take out the head, and when it has cooled, cut the meat off into handsome pieces of about an inch square. Scrape and cut the tongue in the same manner. Lay all these pieces aside. Then put into the water in which the head was boiled about three or four pounds of shin of beef and a knuckle of veal, with the bones broken. Add to this four or five onions, a carrot and turnip sliced, a small bunch of sweet herbs, and some black and Jamaica pepper, whole. Add also the brains, after you have boiled them separately in a cloth, and pounded them. With all these additions, let the soup boil slowly for four or five hours; after which, strain it, and when cool, take off the fat. Take a quarter of a pound of fresh butter, and melt it in a stew-pan; when melted, put in two handfuls of flour, and let it brown, stirring it all the time; add a little of the soup, a sprig or two of sweet basil, and a few heads of parsley. Boil this for a quarter of an hour; strain it through a sieve; then put this, the pieces of meat, and the soup, all together, and boil it for an hour. Add two table-spoonfuls of ketchup, the juice of a lemon, Cayenne pepper, and salt to taste. It is usual to put in at the same time four glasses of sherry wine. When dished in a tureen, put in two dozen of egg-balls.

Egg-balls for mock-turtle soup are made as follows: Boil four or five eggs till they are quite hard. Take out the yolks, and beat them in a mortar, with salt and Cayenne pepper. Make this into a paste with the white of one or two raw eggs. Roll the paste into balls the size of small marbles. Roll them in a little flour, and either fry them in butter or brown them before the fire, being careful to keep them whole and separate. They are now ready for being put into the soup.

Sheep's Haggis.—This Scotch dish is not composed in all cases of exactly the same materials. Some put minced tripe in it, others put no tripe. The following is the most common, and, we believe, the best manner of making it: Procure the large stomach-bag of a sheep, also one of the smaller bags called the king's hood, together with the pluck, which is the lights, the liver, and the heart. The bags must be well washed first in cold water, then plunged in boiling water, and scraped. Great care must be taken of the large bag; let it lie and soak in cold water, with a little salt, all night. Wash also the pluck. You will now boil the small bag along with the pluck; in boiling, leave the windpipe attached, and let the end of it hang over the edge of the pot, so that impurities may pass freely out. Boil for an hour and a half, and take the whole from the pot. When cold, cut away the windpipe, and any bits of skin or gristle that seem improper. Grate the quarter of the liver—not using the remainder for the haggis—and mince the heart, lights, and small bag very fine, along with half a pound of beef-suet. Mix all this mince with two small tea-cupfuls of oatmeal, previously dried before the fire, black and Jamaica pepper, and salt; also add half a pint of the liquor in which the pluck was boiled, or beef-gravy. Stir all together into a consistency. Then take the large bag, which has been thoroughly cleansed, and put the mince into it. Fill it only a little more than half full, in order to leave room for the meal and meat to expand. If crammed too full, it will burst in boiling. Sew up the bag with a needle and thread. The haggis is now complete. Put it into a pot with boiling water, and prick it occasionally with a large needle, as it swells, to allow the air to escape. If the bag appears thin,

tie a cloth outside the skin. There should be a plate placed beneath it, to prevent its sticking to the bottom of the pot. Boil it for three hours. It is served on a dish without garnish, and requires no gravy, as it is sufficiently rich in itself.

Lamb's Haggis.—This is a much more delicate dish, and less frequently made than a sheep's haggis. Procure the large bag, pluck, and fry of a lamb. The fry is composed of the small bowels, sweetbreads, and kernels. Prepare the bag, as in a sheep's haggis. Clean thoroughly the small bowels and other parts; parboil them, and chop them finely along with a quarter of a pound of suet. Mix with dried oatmeal, salt, and pepper, and sew the mixture in the bag. Boil it, and attend to it in the same manner as a sheep's haggis.

SAUCES AND FLAVOURS.

Sauces are liquid preparations, to be used in giving a flavour or relish to dishes, and are of various kinds. A number are formed of melted butter, with an infusion of some other ingredients; others are in the form of gravies drawn from fresh juicy meat; and a third kind are composed partly of water, and some preserves, condiments, or spices. There is little merit in making a good sauce when a person has good and proper materials to make it with. The chief merit consists in furnishing a fine flavour from inadequate materials; as, for instance, giving a rich flavour of meat to a mass of potatoes, or some other plain dish, when no meat has been employed. This can only be done by knowing the qualities of various vegetable products, and how these may be made to resemble the juices of animal food. The vegetable products of which by far the most can be made by a skilful cook are onions, mushrooms, and carrots. Onions and mushrooms alone furnish the most effectual substitutes for animal juices, and may be dressed so exquisitely as hardly to be distinguished from the gravy of beef.

Onion Flavour.—Onion flavour is made by stewing. Take several large onions, and remove the thin outer film from them. Put them in a sauce-pan with a little salt and flour, and a small piece of butter or dripping, to prevent their burning. Cover them quite close, and set by the fire to brown and stew gently. Two hours will dress them, and at the end of this time they will be quite soft, and, with the addition of a little water, they will yield a rich gravy. This may be used to fry potatoes with, or to flavour any other dish.

Mushroom-sauce.—Pick out the stems, and skin the mushrooms and the stems. Cut them in small pieces, and wash them. Then put them in a sauce-pan, with rather more water than will cover them. Let them stew gently for about half an hour, or till they are soft. They will now have yielded a fine rich sauce. Stir in a little flour and butter kneaded together, and season with pepper and salt. This preparation may be eaten with potatoes, the same as meat; it also forms an excellent sauce to many dishes.

Melted Butter.—This must be made of fresh butter. Cut down the butter into small pieces, and put them into a small sauce-pan with cold water, in the proportion of an ounce of butter to a table-spoonful of water. Throw in flour from a dredger with the one hand, while with the other you turn the sauce-pan rapidly round, so as to cause the flour to mix without lumping. A small quantity of flour is sufficient. You now for the first time take the sauce-pan to the fire, and continue turning or shaking it till the butter is thoroughly melted. When it boils, it is ready; it should then have the consistency of rich cream. If it should oil in making, it may be partially recovered by putting a little cold water into it, and pouring it several times into and out of a basin. This sauce is the foundation of a number of other sauces, various additions being made to it for the sake of variety.

Onion-sauce.—Skin the onions, and boil them in plenty of water. When soft, take them from the water, and chop them very fine. Melt butter as above, stir them in, and season with a little pepper and salt.

Egg-sauce.—Boil three or four eggs till they are quite hard. Peel and chop them, and then stir them into melted butter. Season with pepper and salt.

Caudle-sauce for Plum-pudding.—Melt butter, as above directed, and stir into it a glass of sherry, half a glass of brandy or rum, a little sugar, grated lemon-peel, and nutmeg. Do not let it boil after the spirits have been added.

Lobster and Crab Sauce.—Melt the butter, as above directed. Pick out the meat of a boiled lobster or crab; chop it down very fine, and put it amongst the butter. Season with Cayenne pepper and salt. If the lobster be procured raw, with berries or spawn on the outside, these should be taken off previous to boiling, and being mashed in a little cold water, may be added to the sauce after the lobster is put in. By boiling a little, the whole will become a bright red. This forms an improvement on common lobster-sauce.

Mint-sauce.—Take the leaves of fresh green mint. Wash them in boiling water, and after drying them, chop them very fine. Mix them with vinegar, and add a little sugar.

Beef-gravy.—A pound and a half of beef will make a pint of good gravy. Cut the beef in slices, or score it very deeply. Place it in a sauce-pan, with a bit of butter to prevent it from sticking, and a sliced onion. Brown the meat gently, being careful not to let it burn. Cover it closely, and let it stand beside the fire for about half an hour, to allow the gravy to run from the meat. Then put in about a pint of hot water, and let it boil slowly for an hour and a half, with some whole pepper. Some persons put in to boil along with it a piece of bread toasted hard and brown, which thickens the gravy a little, and adds to its richness. Season with salt, and strain it through a hair-sieve.

To make a Stuffing.—Roast veal, fowls, turkey, and some other things require a stuffing. These stuffings have been alluded to in various recipes in the preceding pages, and may here be expressly defined. Take a quarter of a pound of the crumbs of stale white bread, a quarter of a pound of chopped beef-suet or marrow, as much chopped parsley as will lie on a table-spoon, about half a spoonful of chopped sweet marjoram, and a little grated lemon-peel, pepper, and salt. Mix all these thoroughly together with one beat egg and a little sweet-milk. This forms a species of dough in sufficient quantity for a small turkey or large fowl.

Force-meat Balls.—These are balls formed of stuffing, used as a garnish for roast veal or veal cutlets. Make a stuffing like the above; but instead of being wet with one egg and milk, wet the mixture with two eggs. Roll the dough into small balls about the size of nutmegs. Roll them in flour, and fry them with a little lard, butter, or dripping. When required to be more savoury, the composition may be enriched with a little chopped ham, tongue, or sausage-meat.

Raspberry Vinegar.—Pour a bottle of vinegar on two quarts of raspberries—the wild are the best—and let them stand covered for two days. Put through a sieve, pressing the fruit very gently, add to each imperial pint of the liquor one pound of sugar, boil for seven minutes, take off the scum, and when cool, bottle for use.

Raspberry, Gooseberry, and other Jams.—Pick and clean the fruit well, and put on with an equal weight of good soft sugar and a very little water. Boil for twenty minutes, and pot when cool.

Pickles.

Red Cabbage.—Take off the outer leaves, and cut the cabbage into narrow straws. Sprinkle salt over them, and let them lie with a weight on them for two days. Wring the water out of them with a towel, put

then in a jar as much boiling vinegar, seasoned with black and Jamaica pepper, ginger, and a few cloves, as will cover them. Let them stand for twelve hours covered up in a cool oven. *Onions*.—Skin as many small onions as are wanted, throw them into salt and water as they are skinned, and scald them in this. Let them stand in the brine all night. Next day, drain, and pour on them boiling vinegar, which has been seasoned with ginger, white pepper, and mace. *Beet-root* must be boiled till soft—taking care not to break or cut off the fibres, as by doing so the colour would be spoiled—cut in slices, and the boiling vinegar with the spices poured over it. *Common Green Cabbage* should be parboiled, cut into small pieces, dried before the fire, and then have the boiling vinegar and spices poured over it. *Walnuts* make a very useful pickle, as the juice—called walnut ketchup—makes an excellent seasoning for hashes, stews, boiled mutton, &c. Gather the unripe walnuts, prick well with a bodkin, steep in strong brine for ten or twelve days, renewing it every three days. Rub them smooth, and pour boiling vinegar over them, seasoned with pepper, horse-radish, and mustard-seed. They require to be kept for a long time before they are soft and ready for use. The common vinegar sold by druggists, which is mostly diluted pyroligneous acid, answers very well for making pickles.

FISH.

Fish are dressed in a variety of ways, according to taste. They are boiled, broiled, baked, stewed, and fried; but the most common modes of preparation are boiling and frying—boiling when required to be done in a plain way, and frying when a high relish or flavour is to be given to them. In all modes of preparing fish, much care is required to prevent them from being broken or disfigured.

To fry Trouts or similar Fish.—Trouts of a moderate size are dressed whole, and frying is the best mode of preparation. Take the trouts and clean out and scale them. Dust them with flour or oatmeal, and put them in a frying-pan with hot dripping or lard. Turn them, so as to brown them on both sides. Lift them out and serve them on a dish; they will be improved by laying a napkin under them, to absorb the grease. In the country parts of Scotland, trouts are rubbed with oatmeal instead of flour, and some reckon that this improves the flavour.

To dress a Cod's Head and Shoulders.—Take a cod's head and shoulders in one piece, which clean, and let lie among salt all night. When you are going to dress it, skin it, and bind it with tape, to keep it firm. Put it in a fish-kettle, back upwards, with plenty of cold water, a handful of salt, and a little vinegar. Let it heat slowly, and boil for about half an hour. Then let it lie on the drainer across the top of the kettle, for the water to drip from it. After this, place it, back upwards, on the dish in which it is to be carried to table, cutting and drawing away the tapes very carefully. Brush it over with beat egg, strew crumbs of bread, pepper, and salt over it, and stick pieces of butter thickly over the top. Set it before a clear fire to brown. A rich oyster-sauce, made with beef-gravy instead of water, and highly seasoned with Cayenne pepper, salt, and ketchup, is poured in the dish around the fish.

To dress a Middle Cut of Cod.—Clean the piece of cod, and make a stuffing of bread-crumbs, parsley, and onions chopped small, pepper and salt, a bit of butter, moistened with egg. Put this stuffing into the open part of the fish, and fix it in with skewers. Then rub the fish over with beat egg, and strew crumbs of bread, pepper, and salt over it. Stick also some bits of butter on it. Set it in a bachelor's or Dutch oven before the fire to bake. Serve with melted butter or oyster-sauce.

To boil Haddocks, or a cut of Cod.—This is the simplest of all operations. Clean the fish well, and wash and boil with a little salt in the water, the first for twenty minutes or half an hour, the other for about three-quarters of an hour. Eat with oyster-sauce, or melted butter and ketchup.

To dress Haddocks.—This is a most delicious dish when well prepared. Take pretty large haddocks, which clean and wash well. They will be firmer and better if they lie for a night in salt. When to be dressed, wash them and dry them. Cut off the head, tail, and fins; then skin them, being careful not to tear the flesh. Cut the flesh neatly from the bone, and divide each side into two pieces. Dust them with flour, dip them into beat egg, and strew bread-crumbs over them. Fry them in a frying-pan, with a sufficiency of hot dripping or lard to cover them. Be careful that the dripping is not hot enough to scorch the fish. The way to ascertain the proper degree of heat of the fat, is to dip a thin slice of bread into it, and when it makes the bread of a light-brown tinge, put in the fish. If the fat be too hot, it will make the bread of a deep brown. Turn the pieces carefully, so as to brown both sides, and when done, lay them before the fire on a drainer for a few minutes. Serve in a dish, garnished with parsley. Sauce—oyster-sauce, or plain melted butter. The fat in which haddocks are fried will answer the same purpose again, if put through a hair-sieve, and poured in a jar, and kept in a cool place.

To fry Skate, Soles, Flounders, Whitings, and Eels, or any other White Fish.—Skate and soles are skinned and dressed in the same manner as haddocks, but soles are fried whole, not cut in pieces. Flounders are fried in the same manner, whole, but do not require to be skinned. Eels must be skinned and cut in pieces.

To bake Haddocks.—Take two or three haddocks, gut and clean them, and lay them all night among salt. When to be used, skin them, and cut off the heads, tails, and fins. Make a stuffing of bread-crumbs, chopped onions and parsley, and a little bit of butter. Sew this into the bellies of the fish. Rub them over with butter, strew bread-crumbs over them, and bake them in an oven or before the fire.

Fish and Sauce.—Take two or three haddocks, gut and clean them, and lay them all night among salt. When to be used, skin them, cut off the heads, tails, and fins. Boil these trimmings for three-quarters of an hour in a little water. Brown a little flour and butter in a stew-pan, and then strain the liquor, and put it to the butter; add sliced onion, chopped parsley, salt, a little Cayenne pepper, and a spoonful of ketchup. When all this has been boiled for a few minutes, cut the fish in pieces, and let it boil gently till dressed.

To scallop Oysters.—Scald the oysters in their own liquor. Pick them out of the liquor, and lay them in a dish, or scallop-shells, or tins, strewing crumbs of bread mixed with pepper and salt over each layer, and finishing with crumbs. Moisten the whole with a small quantity of the liquor in which the oysters were scalded, and stick pieces of butter thickly over the top. Place the dish before the fire to bake. From ten to twenty minutes will be required, according to the quantity.

PIES AND TARTS.

Pies are of two kinds—meat-pies and fruit-pies or tarts. Both are composed partly of paste, and therefore a knowledge of making pastry is indispensable to the economical housewife and cook. For this operation, the hands should be washed very clean, and care taken to have the board for working upon smooth, clean, and dry.

Under the head of 'Beef-steak Pie,' directions are given for making a light and very wholesome paste, which also answers quite well for tarts, but it can be made a little richer if wished. Dripping, lard, or butter can be used. The first two are cheaper than the butter, but perhaps the best compound is equal parts of lard and butter mixed.

On taking pies from the oven, and while quite hot, the crust may be glazed with white of egg and water

beat together, or sugar and water laid on with a brush; or a little pounded sugar can be sprinkled on tarts before serving. When not used hot, tarts are the better of being slightly heated before using on the subsequent days. Cream may be used with all the tarts.

Icing for Tarts.—After tarts are baked, they are sometimes iced on the top, to improve their appearance. The icing is done thus: Take the white of an egg, and beat it till it is a froth. Spread some of this with a brush or feather on the top or cover of the tart, and then dredge white-sifted sugar upon it. Return the tart to the oven for about ten minutes.

Rhubarb Tart.—Take as much rhubarb as wanted—Victoria is the best kind—skin and cut up into small pieces, fill the pie-dish, and add sugar, a very little water, and a little ground ginger and cinnamon. Put an old teacup in the middle of the pie-dish, as this prevents the juice boiling over. Cover and bake for about three-quarters of an hour.

Gooseberry Tart is made in the same way, the gooseberries being cleaned, and the heads and stems picked off. When the gooseberries are young, no spices are required. Rhubarb and gooseberries make an excellent mixture.

Apple Pie is made with the same seasonings, or with a little pounded cloves, or grated lemon-peel.

Raspberry, Blaeberry, Cranberry, and other Tarts are made in a similar way, but require no seasonings. All require to be picked and wiped, and to have sufficient sugar to sweeten them. The raspberries make an excellent mixture with rhubarb, and the blaeberries with rhubarb or raspberries. Red, black, and white currants, plums, &c., may all be used in the same way. The wild raspberries are the highest flavoured.

Stewed Rhubarb, Apples, Gooseberries, &c., are prepared in the same way as for tarts, and are stewed with sugar, a very little water, ground cinnamon and ginger, and are eaten coldish with cream.

Mince Pie.—Mince pie is a composition of meat, fruit, various spices and seasonings, and also spirits. The following is a properly proportioned mixture: Mince a pound of beef-suet, and a pound of roast-beef, or dressed fresh bullock's tongue; also a pound of apples pared and cored, minced separately from the suet and meat; a pound of currants washed and picked, a pound of stoned and chopped raisins, an ounce of ground cinnamon, half an ounce of ground ginger, an ounce of orange, and an ounce of lemon-peel, and a little salt; half a pound of raw sugar, one nutmeg grated, two glasses of brandy, and two of sherry. Mix all these ingredients together, and lay the bottom of your dish or small tin pans with paste; fill these with the mince, and then cover them with puff-paste. Put in the oven, and bake for half an hour. If the whole of the mixture be not used, what remains over will keep for a long time if placed in a close jar. Some persons do not put any meat in their mince pies.

Open Tarts.—These are tarts without covers, made in flat dishes. Cover the bottom of the dish with a paste, and cut a strip of it and lay round the edge of the dish. Fill in the centre with any jam or preserved fruit. Decorate the top of the jam with narrow bars of paste crossed all over, or stamped leaves. Bake for half an hour.

If there is any paste over, a very good plain tart may be made by spreading with fine treacle, dusting this with ground cinnamon, doubling up like a puff, and firing for a few minutes in the oven. Eat with cream or milk and raspberry vinegar.

PUDDINGS AND DUMPLINGS.

Care should be taken in making puddings to have the suet and the eggs which are put into them perfectly fresh. If there be any doubt of the freshness of the eggs, break each individually in a teacup, for one bad egg will spoil the whole. The cloths used for puddings should be of tolerably fine linen. Let them be carefully washed after using, and laid aside in a dry state, ready for the next occasion. Before putting the pudding into the cloth, dip the cloth in boiling water, and after the water has run from it, spread it over a basin, and dredge it with flour. Every pudding should be boiled in plenty of water, so as to allow it room to move freely; and it must be kept constantly boiling. It is a general saying among cooks, that a pudding *cannot be too well boiled;* and it is certain that there is much more danger of boiling it too short than too long a time. When you take the pudding from the pot, plunge it for a few seconds into a jar of cold water. This will chill the outside, and allow the cloth to be taken away without injuring the surface. The best way to dish a pudding is to place it with the cloth in a basin, then open the cloth, and lay the face of the dish upon the pudding; turn the whole upside down, lift off the basin, and remove the cloth.

Dumplings used formerly to be considered a very indigestible kind of food. By using the baking-powder, however, they can now be made light and wholesome. The paste, as formerly described at p. 757, is made by mixing a pound of flour with a heaped tea-spoonful of Borwick's Baking-powder, adding a quarter of a pound of lard or dripping, or half a pound of suet, making a paste of this with a small tea-cupful of water—hot, when suet is used—lining the dish with the paste, and enclosing with it the fruit, &c., and boiling in a cloth for two and a half to three hours. Rhubarb and gooseberries, blaeberries, or these mixed, and apples, prepared and sweetened as for tarts, and seasoned with nutmeg, answer very well. They are often eaten with a little nutmeg grated on them at table, and a bit of butter added; or they may be eaten with the addition of cream, or a sauce made of butter, a little water and milk, sugar, cinnamon, nutmeg, &c., to taste, and a glass of sherry wine, or half a glass of brandy or rum. No seasoning is needed when blaeberries are used, and cream is their best sauce.

The plain paste, made according to the directions at p. 757, with a quarter of a pound of suet to the pound of flour, can be formed into small dumplings, and boiled without any cloth for about an hour and a half. They are eaten with treacle and vinegar, or they are cut in slices, served round roast-beef, and eaten with it.

A *Roll-dumpling* is made with the same paste as above, rolling it out flat to about a quarter of an inch thick, spreading on it, but not quite to the edges, gooseberry or raspberry jam, marmalade, or other preserved fruit, rolling in a cloth, and tying tightly, boiling for an hour and a half, and serving with a sauce as above.

Yeast-dumplings are much used in some quarters where bread is made in the house, or where the dough can easily be got from the baker. Balls of dough, the size of the hand, are put in boiling water, and boiled for about twenty minutes. They should be eaten with butter and treacle, sugar and vinegar, or raspberry vinegar, the moment they are ready; and they are known to be ready when a fork stuck in them comes freely out.

Plain Rice-pudding.—Take a tea-cupful of rice, wash clean, put in a dish with three breakfast-cupfuls of milk, two tea-spoonfuls of sugar, a little salt, and a little ground cinnamon. Set in a very cool oven, or on the girdle, and let the whole simmer for three hours. Eat plain, or with raspberry jam and a little raspberry vinegar, or gooseberry jam, and cream or milk.

Semolina or Manna-croup Pudding.—Take half a pound of semolina, and put it in a pan with an imperial pint of milk, and the same of water, a bit of butter, a very little salt, and a table-spoonful of sugar. Keep stirring, and boil for ten minutes; season with five drops of essence of almond, and twenty drops essence of lemon. Serve in a dish with bits of jam round it, or in a shape, and eat warm or cold, as above, with jam, cream, &c.

Rice-shape.—Take a pound of whole rice, wash well, and put in a pan with a quart of milk, the same of water, a bit of butter, a little salt, and six or eight pieces of lump-sugar; and simmer very slowly with closed cover, without touching, for three hours. Flavour as above, when ready, with essences of almonds and lemon; press into a shape, and eat cold with jam, as above, and cream.

A plainer mode of eating rice is to prepare it as directed for a curry, p. 758, and eating with jam and cream, as above.

Plum-pudding.—A plum-pudding may be made either rich or plain, according to the quantity of fruit and spices put into it. The following is the direction for making what would be considered in England a *good Christmas-pudding:* Take a pound of good raisins, and stone them; a pound of currants, which wash, pick, and dry; a pound of rich beef-suet minced, and a pound of stale bread-crumbs, and half a pound of flour. Mix the bread, flour, and suet in a pan. Beat six eggs in a basin, and add to them about half a pint of sweet-milk. Pour this egg and milk into the pan with the suet and flour, and beat it well with a flat wooden spoon for some time. Then stir in the currants and rasins, mixing well as you proceed; mix in also a quarter of a pound of candied orange and lemon peel, cut in thin small pieces, an ounce of powdered cinnamon, half an ounce of powdered ginger, a nutmeg grated, and a little salt. Next add a glass of rum or brandy. The pudding is now made, and ready to be either baked or boiled, according to taste. If to be baked, butter your tin or basin, and put the pudding into it, and bake in an oven for an hour and a half, or nearly two hours. If to be boiled, pour it into a cloth; tie the cloth, allowing a little room to swell, if made of bread, and boil for six hours. Serve with caudle-sauce.

Carrot-pudding.—Take half a pound of suet, the same of flour, some bread-crumbs, currants, stoned raisins, ground ginger, and cinnamon, grated nutmeg, sugar, a very little salt, and one large carrot grated. Mix in a basin, moisten with a little milk, boil as above for four hours, and eat with the same sauce.

Currant-pudding.—An excellent family pudding may be made of the following ingredients: A pound of minced suet, a pound of bread-crumbs or flour, three-quarters of a pound of currants, washed and picked, a little powdered cinnamon and grated nutmeg, and a very little salt. Beat two eggs, and add as much milk to them as will wet the whole. Mix all together, tie in a cloth, as previously directed, and boil for three hours. Serve with caudle or any simple sweet sauce.

Bread-pudding.—Boil as much milk as will be sufficient for the pudding you want. When it begins to boil or rise in the pan, pour it upon crumbled-down stale bread in a basin. The quantity of bread should be as much as will thicken the milk to a stiff consistency. Cover it up for ten or fifteen minutes, to allow the bread to swell. Then beat or mash it up to make a fine pulp, stirring in a small piece of butter. Beat three or four eggs, a tea-spoonful of ground cinnamon, a little grated lemon-peel, and sugar according to taste. Stir this among the pudding. A little brandy or rum may be added; also a few currants, if required. The pudding may be either boiled or baked. If to be boiled, put it in a well-buttered pudding-shape or basin, with a buttered paper over it, and also a cloth over all: boil for an hour. If to be baked, put it into a buttered baking-dish, and bake in an oven for half an hour.

Rice-pudding.—Take a pretty large cupful of rice, pick it, and wash it well in cold water. Boil it in water for about five minutes. Drain the water off, and put it on again with as much milk as you require. Let it boil till the rice is quite soft, stirring it frequently, to prevent it from burning. When done, put it into a basin, and stir in a piece of butter, or some suet minced very fine. When cold, add to it four eggs, beaten, with a little ground cinnamon, grated nutmeg and lemon, and sweeten with sugar. All is to be mixed well together. It may be either boiled or baked, as directed for bread-pudding. The above composition may be enriched by using more eggs and less rice, also by adding currants, spirits, and candied orange-peel.

Custard-pudding.—Take four eggs, and beat them well with two table-spoonfuls of flour and a little cold milk. Season this with sugar, ground cinnamon, grated lemon-peel, and pour on a pint of boiling milk, stirring all the time. It may be either baked or boiled. By using more eggs, the flour may be omitted.

Bread-and-butter Pudding.—Cut several slices of bread rather thin; butter them on one side; put a layer of them in a pudding-pan or dish, and a layer of currants above; then another layer of bread; and so on till the dish is full. Beat four eggs, with a little ground cinnamon and nutmeg, also some sugar. Add milk to this, till there is sufficient to fill up the dish. Then pour it over the bread, and allow it to stand for a time to soak. It will now be ready for either baking or boiling, as directed for bread-puddings.

Tapioca-pudding—Sago-pudding.—Take a quart of milk, and put in it six table-spoonfuls of tapioca. Place it on the fire till it boil; then sweeten to taste, and let it simmer for a quarter of an hour. Stir it frequently, and be careful that it does not burn. Then pour it into a basin, and stir into it a little fresh butter and three eggs well beaten; you may now pour it into a buttered pudding-dish, and bake for about an hour; or, after adding another egg, boil it in a basin or mould for an hour and a half. Sago-pudding may be made in the same manner.

Batter or Yorkshire Pudding.—Take a quart of sweet-milk, and mix in it a large cupful of flour, making the mixture very smooth. Beat four eggs, and strain them into the batter. Add a little salt, and mix all well together. Butter your dish or tin, and pour the batter into it. Place the dish either before the fire under roasting meat, or under meat sent to the oven. The pudding, when done, easily shakes out of the dish into another dish to be carried to table. It should have a nicely browned appearance. When dressed before the fire, either turn the pudding, or place the dish a short time on the fire to brown the under side. It is eaten before or with the meat.

Pease-pudding.—Pick a quart of split pease—that is, remove all impurities, or discoloured pease, or shells. Tie them loosely in a cloth, leaving plenty of room for the pease to swell. Boil till they are soft, which may be in from two to three hours. Take the pudding from the water, and put it into a basin. Open the cloth, and bruise or mash the pease well. Mix in a piece of butter, with pepper and salt. Then tie it up tightly, and put it into the pot again, and boil for about half an hour. When ready, turn it out of the cloth into a vegetable dish. If properly managed, it will turn out whole.

Pancakes.—Take three eggs, beat up with a little pounded loaf-sugar, add a small table-spoonful of flour for each egg, and rub till smooth. Put in as much milk as will make the whole of the consistency of cream, three drops of essence of almonds, two of cinnamon, and eight of lemon. Put a bit of butter or dripping in the frying-pan; make hot, and pour in half a tea-cupful of the batter, so that it cover very thinly the bottom of the pan; and brown lightly. Slip a knife under the edge all round, and roll up, fold into three, and lay on the dish. Sprinkle a little pounded loaf-sugar, and eat very hot with raspberry vinegar. When put out in this way very thin, it is unnecessary to turn them.

German Pancakes.—Take a slice or two of a stale pan-loaf, cut half an inch thick; take off the crust, and cut into bits about two inches square; soak in milk for three minutes; have ready two eggs; beat up with a little ground cinnamon, nutmeg, and sugar; dip the bread in the beat egg, and fry on both sides till of a light-brown. Eat with raspberry vinegar.

MEDICINE–SURGERY.

ERROR in diet, drink, dress—in fine, the erroneous treatment of ourselves as organised beings—is sure, sooner or later, to be productive of bodily ailment. Even were we faultlessly nurtured as to food and clothing, and were we born with perfectly sound constitutions, still we are liable to injury from numerous external causes; such as weather, climate, accidents, &c.; hence the necessity either for remedial agents, in the shape of *medicines*, strictly so called; or for aid, in the form of *surgical* operations. A man, for instance, may be afflicted with some internal or external malady, and he has recourse to a medicament or healing substance, with the hope that it will remove his affliction, and restore him to health. Again, he may have received such bodily injury, or his malady may have assumed such a form, that an internal medicine would be unavailing, and he submits to the instrumental operations of the surgeon. Thus, it is customary to distinguish between the surgeon, physician, and the apothecary or chemist, whose business it is to prepare or compound drugs; and such distinctions are not without their advantages.

In the following pages, therefore, while separating Medicine from Surgery, we follow no technical distinction further than seems likely to facilitate the ordinary reader's comprehension of an art as necessary to his wellbeing as those which relate to his food and clothing. Our utmost aim is to convey to the class whom we more especially address a general notion of the science; those who seek for more will find themselves disappointed. To adopt the language of a recent medical writer: 'No one who reads herein is to expect that he is to find a whole body of surgery, or that he will be fitted thereby to set up for an amateur surgeon, capable of practising upon himself or his neighbours, for a vast deal must be passed by. Not that there are any "secrets of the prison-house" to be kept; but everything cannot be told, usefully at least, to general readers, for this simple reason—that were it set forth, they could not rightly comprehend it. Still, there is much to be mentioned which may be of good service on emergency, without interfering with the doctor.'

MEDICINE.

All those drugs which in some form or other are applied to the alleviation or cure of bodily ailments, are known by the name of medicines; and they consist for the greater part of substances prepared from vegetables and minerals, a few only being of animal origin. As to the history of the earliest employment of medicinal agents, no tribe is so rude as not to have discovered the remedial virtues of certain plants. Chance would probably determine, in the lapse of time, the uses of many. Indeed, at no very distant period, one of our most valuable medicines was discovered by mere accident. A quantity of Peruvian bark had been thrown as useless into a small well, out of which some soldiers afflicted with the ague had the good fortune to drink. To their own surprise, as well as that of others, they became rapidly well, and the cure, happily, was attributed to the right cause. In the same manner, a knowledge of many important medicinal articles has been attained, and occasionally some bold inquirer has arrived at the same end by actual experiment. As among the African and North American tribes of the present day, however, a great portion of the medical art of our forefathers lay in working on the fears and imaginations of the patients by means of pretended charms and incantations. The effects of mesmerism, and of homœopathic globules, in the treatment of disease, as well as of many other forms of quackery, are explicable through their influence upon the imagination—the faith or the fears of the sufferers.

The medicinal preparations of the ancients were taken almost entirely from the vegetable kingdom, though the Arabian school of medicine, which arrived at great eminence while the Saracens were masters of Spain, was well acquainted with several metallic remedies. The researches, however, of the chemists, or rather alchemists, of the dark ages, first brought fully to light the great value of the metals in the hands of the physician, and this credit these ingenious individuals are at least entitled to, though we may smile at their absurd attempts to transmute baser minerals to gold, or to find out the elixir of life. They made thus a most important addition to the number of medicines, and effected a change in the healing art which is felt to the present time. The liability of herbs to spoil by keeping, whether in the state of roots, leaves, or seeds, gave a great superiority to the mineral preparations, which retain their powers for a long period. At the time when they were first introduced, the sensation excited was so great, that the numerous believers in their virtues were called, in contradistinction to the admirers of vegetables, the chemical school. The discovery of the circulation of the blood founded a new set of philosophers, who maintained that the body was entirely framed upon, and regulated by, mathematical laws. Though this doctrine was supported by some eminent men, and for a short time superseded the chemical theory, yet its total failure to account, upon mechanical principles, for all or for any of the vital actions, soon caused it to fall into disrepute.

It is scarcely necessary to mention any other changes in the progress of the science of medicine, and indeed those taken notice of are of consequence only from their effects on the nature of the remedies for disease. During the eighteenth century, anatomy was prosecuted with deep attention, the nature of medicinal preparations closely investigated, and their number increased; the result of which was, the reduction of the practice of physic to principles more agreeable to reason and to truth. Men, too, partaking of the wide spread of knowledge during the period mentioned, began to object to nostrums when labouring under illness, and became reluctant to swallow a dose without being informed of the nature of the action, and the effects expected. Hence medicines, instead of being applied indiscriminately to every species of disease, were arranged into some sort of order, and classified according to their known or supposed operation. This is the most simple method of viewing the range of medicinal substances, and it is the one we shall adopt in the present instance—though the small space at our disposal, as well as the scope of the present observations, prevents more than an enumeration of the most common medicines.

MODES OF ACTION OF MEDICINES.

Some substances employed in the cure of disease act *mechanically*, and others *chemically*, on the system; but by far the greater proportion of them act *vitally*.

A medicine is said to act *mechanically* when its effect on the body is the same as that which it exerts over inanimate matter. Demulcents, for instance, or remedies taken to remove the acrid effects of some other substance, operate simply by coating the stomach with a gummy fluid, an action which is entirely mechanical. The *chemical* operation of medicines may be thus explained: When an acid and an alkali are mixed in a glass of water, they unite together, and form a third substance, a salt, having new properties altogether. The same chemical process takes place when sourness, or an acid, is neutralised in the stomach by soda, or any alkali. The *vital* action of medicines differs totally from the two former. In this case, the substances are absorbed into the blood, and are conveyed by the vessels of the heart to the quarter whither their nature determines them, and in which their special action is manifested. Diuretics, or medicines which stimulate the urinary organs, may form an example of vital action. From the stomach, the diuretic is absorbed into the blood-vessels, and carried to the kidneys, stimulating them to the secretion of urine, though by what process this fluid is there separated from the rest of the blood, we know not. Under these three divisions, then, *mechanical*, *chemical*, and *vital* agents, all the articles used in medical practice—technically, *materia medica*—are comprehended.

Although scientific medicine does not stoop to cheat the imagination of the patient, it does not ignore the beneficial assistance that may be afforded in the treatment of disease by the mental affections, and through the external senses. Thus, in nervous disorders, it recognises and avails itself of the soothing influences of quietness and of melodious or monotonous sounds. In fainting, hysterical attacks, &c., it operates upon the senses, stimulating the olfactory organ with ammonia, vinegar, &c.

Nervous and mental maladies are often observed to be influenced by various degrees of light or darkness, by change of scene, and by the degree in which hope or confidence in the measures adopted can be realised.

Alphabetical Classification of Medicines according to their Effects.

Antacids, as the name imports, are those medicines which correct acidity of the stomach and digestive organs. The stomach of many individuals is liable to a continued conversion of their food, particularly vegetable food, into a species of acid, which produces the annoying feeling called heartburn. This acid may be neutralised by any of the alkalies, and the process of relief is as purely chemical as if it were performed in a glass of water for experiment. The three alkalies, potass, soda, and ammonia, the alkaline earth magnesia, and carbonate of lime (chalk), are the most useful medicines of this description. The relief obtained from them is, as might be expected, merely temporary, since they do not prevent the generation of the acid anew. Antacids should in general be prescribed along with vegetable tonics, and in no case ought their administration to be long persisted in without occasional interruptions, as they cause thinness of the blood if used too long. It is further necessary to observe in what condition, and in what region, the acidity more particularly manifests itself, as all antacids have not precisely the same properties and modes of action. Thus, the best corrective for gaseous acidity in the stomach is found to be ammonia and its carbonate, and magnesia; and where acid exists in the urinary organs, potass and soda are preferable. Calcined magnesia is one of the simplest and best known of the antacids. It is employed in indigestion, attended with acidity of the stomach and constipation; in which cases it is generally preferred to the other alkalies, as being less irritant, and as the combinations which it forms with the free acids of the stomach are gently laxative. It is also administered with much advantage in the acidity attendant on infantile diseases.

Anthelmintics, also known as *Vermifuges*, are those drugs possessing the property of destroying worms, or expelling them from the intestinal canal. Other medicines, as the more active purgatives, may also effect this purpose. Among the more common vermifuges may be mentioned powder of tin, oil of turpentine, pomegranate bark, powdered fern-root, Corsican moss, and worm-seed. 'As the action of these remedies is merely temporary,' says Dr Neligan, 'it will be requisite, as soon as the worms are expelled, to employ means calculated to restore the digestive organs to a healthy state, and to correct that peculiar character of them which promotes the generation of intestinal worms. The means best calculated for this purpose are: Keeping the surface of the body warm by proper clothing; a light but nutritious diet, with a moderate use of common salt; and at the same time the administration of bitter tonics, with gentle aperients.'

Antispasmodics are used to remove spasms or convulsive contractions of the muscular fibre in the body, and are very similar in their action to the class Narcotics. Opium, ether, camphor, ammonia, chloric ether, valerian, galbanum, and asafœtida, with most of the narcotics (which see), are the antispasmodics generally in use.

Aperients or *Cathartics* is the general term for those numerous medicines which quicken or increase the action of the bowels. As they differ considerably in their effects, they are usually spoken of as *laxatives* or *aperients*—that is, gentle evacuents; *purgatives* when more powerful; and *drastics* when they are particularly powerful and energetic. Whatever be their energy, they may be arranged under three heads: 1. Those of an oily or saccharine nature; 2. Those which are derived from vegetables, such as resins and extracts; 3. And those formed by a combination of acids with earths, alkalies, and metals, termed neutral and metallic salts. The operation of all these three is of the character of an irritation upon the mucous or inner membrane of the bowels, though in their effects they differ considerably from each other. The first mentioned seem simply to discharge the contents of the bowels; the second appear to increase the quantity of matter evacuated, by stimulating the mucous membrane, and increasing the natural flow of mucus; while the third class produce evacuations of a watery consistence.

The principal purgatives of the *first* kind are, castor-oil, manna, tamarinds, and so forth. Castor-oil is one of the most useful and safe medicines of the purgative class. The others mentioned are exceedingly mild in their operation, and are generally employed merely to palliate or disguise the bad flavour of some stronger drug.

The *second* kind of purgatives includes aloes, scammony, jalap, colocynth, senna, and rhubarb. The general character of all these has been given above, though the rhubarb possesses one remarkable distinction from the others. It is supposed to act on the muscular membrane of the bowels, producing a natural discharge simply, and afterwards acting as a tonic.

The principal neutral and metallic salts, which form the *third* order of purgatives, are sulphate of soda, Epsom salts (sulphate of magnesia), cream of tartar (supertartrate of potash), phosphate of soda, and calomel (submuriate of mercury). The latter is the most universal in its application of all medicinal preparations. But in proportion to its usefulness, so is its danger when misapplied. The dose should be small, and combined with rhubarb, jalap, or scammony, as it has been found occasionally, when taken alone, even in a single dose, that salivation was produced. The frequent use of calomel as a common purgative is to be strictly guarded against—for it must be borne in mind that calomel is one of the most potent of drugs, either for good or for evil—and the less frequently it is taken

the better. With respect to the others, little can be added to the general description already given; it may be mentioned, however, that the pleasantest, though not the cheapest of all medicines, is the phosphate of soda, or *tasteless salts*.

As cathartics of some kind or other are very largely —perhaps too largely—used in this country, where there are so many sedentary and indoor employments, it may be well to transcribe a few remarks from one of the fathers of modern medicine on the subject: 'The operation of cathartics,' says Gregory, 'is dangerous to the weak, the irritable, the slender. It is also to be attempted with great caution, even by the gentlest medicines, in inflammation of the stomach and intestines, or when these are in a delicate state, as in dysentery or protracted diarrhœa. Too frequent repetition of purging, though at first necessary, does great injury, both to the whole system, which it weakens exceedingly, and especially to the intestines themselves, which it sometimes renders preternaturally feeble, tender, and irritable, but more frequently torpid and slow; whence proceeds constipation, and a necessity of having habitual recourse to cathartics. It also renders the blood thin and pale, in the same manner as too frequent blood-letting. . . . . But where necessary, due allowance should be made for the patient's idiosyncrasy, not only in regard to the nature of the medicine, but also to its quantity, mixture, preparation, and time of taking it. During the operation of cathartics, patients are very easily injured by cold, possibly not more by reason of the body being then weakened, than on account of the current of fluids being drawn off more than usual from the external parts: it is therefore proper at such a time to guard carefully against exposure.'

Astringents, as commonly defined, are substances which produce contraction and condensation when they come in contact with living matter; their mode of action, however, is rather obscure. Their power appears to depend in a great measure on the presence of the principle called tannin, and they produce their effect by bringing into closer contact the particles of the body to which they are applied, without in other respects affecting its mechanical structure. They are believed to be often of service in restoring tone to the stomach, and it is evident that their astringency will be of great advantage when any laxity of the surface of that organ exists; hence in many instances the most powerful tonics will be obtained from the class astringents. All the vegetable astringents contain tannin; and those most generally employed are preparations from gall-nuts, catechu, kino, oak-bark, logwood, and creosote. A number of the acids, and some of the salts, those particularly in which the acid preponderates over its base, as in alum, which is a compound of vitriol and the earth alumina, possess astringent properties, although they contain no tannin. Some of the metallic salts, as superacetate of lead (sugar of lead), and sulphate of zinc (white vitriol), are ranked in this class. Cold is also a direct astringent, and is often employed in this character with great advantage in checking bleedings. 'All the astringent medicines taken from the vegetable kingdom,' says Gregory, 'are so mild and safe, that they may be taken inwardly, and the use of them long continued without difficulty or danger, in larger or smaller doses, according to the strength of each; but those from the mineral kingdom cannot always be so employed; indeed, they are fitted more for external than for internal application.'

Carminatives are those medicines which produce the discharge of flatulence from the alimentary canal. This malady is more annoying than dangerous, though it rises occasionally to a most painful height. The warm essential oils, such as caraway, anise, or peppermint, and some aromatic stimulants, as cinnamon and ginger, are the carminatives in greatest repute.

Caustics are a class of substances employed to create artificial sores or ulcers, often employed for the purpose of relieving some deep-seated malady. The operation of caustics is considered chemical, being the result of some attraction between the animal body and the substance employed. The same action takes place on the application of caustics to a portion of the dead subject. Where suppuration is going on in any internal part, they are exceedingly useful in creating a drain on the surface of the body. The principal caustics employed in medicine are potass, blue vitriol, nitrate of silver, arsenic, and some preparations of mercury. The nitrate of silver, or lunar caustic, is the substance in most common use, chiefly on account of its great manageableness, in consequence of its solid form, its property of not deliquescing, and its mild but effectual action—the pain produced by it being but of short duration. There is also a milder action of substances that are usually denominated caustics. Thus, nitrate of silver (lunar caustic), when dissolved in water, exerts very beneficial astringent or sedative action upon the skin and mucous membrane, according to the strength of the solution. From two to five grains, dissolved in one ounce of water, forms a most valuable lotion in most common kinds of inflammation of the eye. A stronger solution, from half a drachm to a drachm in the ounce of water, may be very successfully painted on the inside of the throat, in inflammations of that part. Nitrate of silver, sulphate of copper (bluestone), concentrated acetic acid, and nitric acid, are employed as caustics for the destruction of warts; and only require care that they do not spread to adjacent parts.

Counter-irritants—known also as vesicants and rubefacients—are substances which produce redness, vesication, or inflammation, when applied to the skin. The extremities of the vessels which convey the blood from the heart over the body, are supposed, when they terminate on the skin, to divide into minute tubes, one kind of which carries the red globules, and another the colourless serum of the blood. When strong stimulants, such as mustard or Spanish flies, are applied to the skin, they are supposed to excite these minute vessels so powerfully, that those which contain serum become filled with red globules; hence the term *rubefacients*. This can only be produced during an extraordinary flow of blood to the part, and is the cause of the redness consequent on the application of mustard cataplasms or blisters. A blister is simply a rubefacient allowed to remain on the skin until the deeper layer of it becomes affected, and pus or serum exudes. Like caustics, blisters are exceedingly useful in substituting a superficial inflammatory action for one existing in some deeper and more dangerous seat, and they are hence called *counter-irritants*. The principal substances employed in exciting cutaneous inflammation are Spanish flies, mustard, tartarised antimony, ammonia, turpentine, and a few other drugs of a stimulant nature. The Spanish flies are almost exclusively used in blistering; and mustard, as a rubefacient, is held in a similar degree of estimation.

Demulcents—known also as *emollients*, *diluents*—are a class of medicinal agents the operation of which seems entirely mechanical. A poultice is applied externally to soften an inflamed or irritated part, and with exactly the same views are demulcents or diluents used to soothe any irritation of the alimentary canal. Solutions of gum, and sirups, with barley-water, rice-water, and other farinaceous drinks, are employed for this purpose. Iceland moss (*Lichen Islandicus*), liquorice-root, almonds, figs, sugar, marsh-mallow, linseed, and others, are included in the class of demulcents.

Emollients are generally ranked under two great classes—the oleaginous and mucilaginous. Whether taken internally, or applied externally as Fomentations (which see), their action is simple and easy to be understood: the solid parts are rendered elastic or resisting, but more flexible; and of consequence some parts, which

previously hardly admitted of motion, are afterwards moved with much greater ease. 'Of all medicaments of this kind, by far the most powerful and certain is pure water, especially when warmed; for the innumerable decoctions, fomentations, and infusions which are so frequently prescribed, and so much celebrated for their emollient qualities, are generally nothing else, and have no other virtue than pure warm water.' Oily and mucilaginous emollients have one advantage over pure water, that they are not so soon dissipated by evaporation.

Fomentations are warm fluids, applied for the purpose of encouraging perspiration on the skin, and thereby to diminish inflammation, and to render the skin yielding, so that the swelling which accompanies inflammation may be less painful, by the greater readiness with which the skin yields than when it is harsh and dry. The usual practice, therefore, of rubbing, dabbing, or pressing, is improper. The patient must be as well defended as possible from exposure to wet, by having something placed under him; and then a piece of thick flannel, or blanket, after being saturated in the warm fomentation, is to be instantly wrung, and laid liberally on the part of the body affected, and covered with oiled silk or a jack-towel, to keep in the warmth. This process is to be repeated every ten minutes or so, for hours if necessary. The foot or hand may be fomented by mere immersion, the heat of the fluid to be kept up by the addition, from time to time, of more which is hot. Warm water, as already stated, makes of course the readiest fomentation, and is generally the best.

Diaphoretics are those remedies which promote the insensible perspiration; *Sudorifics*, such as produce profuse perspiration or sweating. These two classes of remedies are very closely connected, and scarcely, if at all, admit of being distinguished; the effects differing rather in degree than in kind. With regard to their action, it seems to be sympathetic rather than direct: nausea and vomiting produce profuse sweating; sudden fears, and other mental emotions, do the same thing; and all the diluents, stimulants, sedatives, and emollients act less or more in this way. Among the simplest diaphoretics may be ranked whey, gruel, barley-water, and other warm drinks and infusions. 'Among the most excellent and salutary diaphoretic remedies,' says Dr Gregory, 'is deservedly reckoned proper bodily exercise; for when moderate, it accelerates the circulation, and eminently promotes perspiration: when more violent, it generally induces a profuse sweat, even in those persons who can scarcely be compelled to sweat by the medicines commonly used. Among the most active *sudorifics* may be enumerated warm drinks; the warm bath; the preparations of antimony, including James's powder; Dover's powder (compound ipecacuan powder); the preparations of ammonia; and all medicines generally which nauseate the stomach. Probably, of all these, Dover's powder is the best. Sudorifics, in almost all cases, when early used, prevent the effects of colds, which, when neglected, prove so often fatal in their consequences. During the administration of sudorifics, it is essential that the surface of the body should be kept warm; and for this purpose, a bad conductor of heat, such as flannel, should be employed. Care also must be taken to avoid the application of cold, either by exposing the surface of the body to cold air, or by the use of cold drinks while the perspiration continues, or for some time after it has ceased; lastly, when it is wished to check the perspiration, this must be done gradually, by drying the surface of the body with dry warm towels, by diminishing the covering, and by cautiously exposing the hands and arms to the air.

Diuretics are those medicines which operate in promoting the flow of urine, by stimulating the action of the kidneys, the organs which secrete it. This class is very numerous, though the manner of their operation, like that of all the other vital agents, is not thoroughly understood. 'In whatever manner the action of diuretics is produced, the general effect is to diminish the watery part of the blood, and by this means promote the absorption of fluid effused into any of the cavities or into the cellular membrane. Hence dropsy is the disease in which they are principally employed; and when the discharge of urine can be excited by their administration, the effused fluid is in general removed more speedily from the system, and with less injury to the patient, than by any other method.' The diuretics chiefly employed in practice are squills, foxglove, juniper-berries, potash, cream of tartar, acetate of ammonia, nitric ether, and Spanish flies. All these act powerfully on the urinary organs—those in highest repute being squills, foxglove, juniper, and cream of tartar. The first and the last of these are the most efficient, being more certain in their effects than the others. (Foxglove and Spanish flies, being powerful poisons, should not be used by other than professional direction.) The action of diuretics is much affected by the state of the skin; hence the common rule, during their exhibition, to keep the surface of the body cool, and to promote the operation of the dose by the use of simple diluent drinks. Further, from the nature of the above-enumerated substances, it is sufficiently clear that some of them are decidedly heating, others refrigerant; some considerably increase the acrimony of the urine, others diminish and blunt it: so that it is quite evident that all of them cannot be equally adapted to every disease.

Emetics are substances administered for the purpose of producing vomiting. It may be supposed, from their being received into the stomach, and acting directly and speedily upon it, that there is no absorption into the blood necessary. Tobacco, for instance, taken into the stomach, excites vomiting; but it is from its reception into the circulation; because, if the tobacco be laid on the arm, the same effect will be produced. Some emetics, indeed, appear to act principally on the muscular covering of the stomach, exciting it to contraction, and thereby causing the expulsion of the contents. Most of them, however, simply produce nausea, which causes the inversion of the receptacle of the food. The most active emetics employed in medicine are tartar-emetic, ipecacuan root, chamomile flowers, mustard, and sulphate of zinc. The first two of these are most commonly used; the second of the two being the gentlest, and perhaps on that account the safest, in ordinary cases. 'Emetics should be employed with great caution where there are symptoms of determination of blood to the cerebral organs, in consequence of the obstruction of the circulation which is occasioned during the act of vomiting; for the same reason also they ought not to be administered in diseases of the large arteries, as in aneurism. From the violent action of the abdominal muscles which is caused, the act of vomiting is attended with great risk in the advanced stages of pregnancy, in hernia, and the like.' Frequent vomiting is very injurious to the body, as it weakens the stomach, of course spoils the digestion, and thus in some measure becomes necessary. The operation is more easy with a full than with an empty stomach; hence the advantage of drinking pretty copiously during the exhibition of emetics. It is often of advantage, especially in very infirm patients, or those who have been much agitated, to give an anodyne after vomiting, to compose such agitation, procure sleep, and recruit the health.

Expectorants, or *Pectorals*, as they are sometimes termed, are substances used to promote the expulsion from the lungs of those fluids which are secreted during colds, and lodge there, causing difficult breathing, and sometimes ending in injury of their structure. Thus those remedies which promote expectoration are of great consequence to health, though often neglected. The principal medicines of this class are antimony, squills,

ipecacuan, balsam of Tolu, and gum ammoniac. Sirup of squills is the preparation in greatest use, forming one of the best expectorants we possess for the pulmonary affections of children, in doses of from ten to thirty minims. To these may be added all emetic substances which, by their mechanical action, dislodge accumulated secretions from the respiratory organs, and thus frequently become valuable agents in the treatment of diseases requiring the application of expectoral drugs. To these may be added all Diaphoretics, the inhalation of steam of warm water, which acts as an emollient, and riding on horseback, which has been much recommended.

Febrifuges are medicines employed to remove fever. They necessarily will vary nearly as much as the characters or types of fevers vary. Thus, simple fever is removed by aperients and salines, or diaphoretics—for example, a few doses of James's powder, or Dover's powder. Fevers, however, of a lower character, such as the typhoid or nervous fever, more frequently require the administration of stimulants. Again, fevers of the intermittent or periodical type, such as ague, are cured by quinine. The word febrifuge, therefore, is obviously one of very wide application.

Narcotics—known also as *Anodynes*, *Soporifics*, and *Hypnotics*—are those substances which tend to remove irritation or pain, inducing in general a state of repose. Before this quieting effect is produced, however, there is a primary excitement of short duration, which is well exemplified in the case of opium. *Sedatives*, viewed as a separate class, are believed to allay pain and promote sleep, without possessing any stimulating qualities. Unless where excessive pain is present, narcotics may be regarded as a class of medicines *only to be used with great caution, and never free from danger.* Opium and its preparations, lettuce extract, henbane, foxglove, Indian hemp, hemlock, belladona, and tobacco, are some of the strongest narcotics. It is difficult to say which of these is the safest: 'idiosyncrasy,' says Dr Neligan, 'has a remarkable influence on the effects of narcotics: we meet with some individuals almost insensible to their action; while in others, small doses produce a dangerous stupifying effect, or in some instances give rise to a degree of excitement amounting to furious delirium. But habit influences the action of narcotics on the system more than any other circumstance—their power being diminished in an extraordinary degree by repetition. Where, therefore, their continued administration is required, it will be necessary gradually to augment the dose, in order to produce their usual effects. The influence of age on their action must be also borne in mind in their administration, *the young being much more susceptible to their influence than individuals of maturer age.*' It is, indeed, scarcely ever safe to administer opiates to infants. *Sedatives* are those substances which directly or primarily depress the vital powers without inducing any previous excitement. From their effects, which are directly contrary to those of stimulants, they are sometimes termed *Contra-stimulants;* occasionally, *Calmatives.* With regard to the distinction which is made between them and narcotics, Dr Neligan remarks: 'Were we merely to theorise on their mode of action, it would be perhaps difficult to draw an exact line of distinction, but when we come to consider the remedial powers of the medicines classed under each head, it will, I think, be at once evident how *practically* essential it is that we should recognise this as an especial class of remedial agents.' Among sedatives are to be found the most potent poisons. The diseases in which these remedial agents are employed are those of over-excitement of the nervous and vascular systems.

Refrigerants are substances calculated to diminish the heat of the body when morbidly increased, and to produce a soothing sensation of coolness. Applied externally as cooling or evaporating lotions to any inflamed part, their operation is easily understood, as they serve merely to reduce the temperature by carrying off the excess of heat. Taken internally, their mode of action is not quite so clear, for though they produce the sensation of coolness, they do not in reality reduce the temperature of the body. The most common refrigerants are vinegar, citric acid, tartaric acid, lemon-juice, the fruit of the orange, nitrate and chlorate of potash, and conserve or confection of dogrose. The principal use of these preparations in practical medicine, is in the treatment of fever and inflammatory affections, in which their direct action on the stomach seems to occasion sympathetically a reduction in the force of the circulation.

Soporifics, a familiar term for the milder agents of the class Narcotics or Sedatives.

Stomachics and *Tonics* form another class of medicines, acting by absorption into the blood, or as vital agents, which cannot be ranked either amongst those that excite action, or those that repress it. The former increase the digestive powers of the stomach, the latter renovate the tone or contractile energies of the muscular fibre. They are slow in their operation, and augment the strength of the body without materially exciting its actions. As these two kinds of medicines are not very distinctly separable, it may be better to enumerate them together. Good nutriment is the most natural and best supporter of the bodily powers; but to effect this purpose, it is necessary that the function of digestion should be in a proper condition. Gentian root, quassia, chamomile, calumba, and canella, assist powerfully this object. Amongst the tonics, Peruvian, cascarilla, cinchona, angostura, and willow barks, the preparations of iron, the sulphuric and nitric acids, are in greatest repute. 'There is no class of remedial agents,' says a high authority, 'which requires more discrimination in their administration than tonics, nor any the injudicious use of which more frequently produces evil consequences. The diseases in which this class of remedial agents are principally employed must manifestly be those of diminished power. In no case, however, should they be prescribed where there is a tendency to irritation or inflammation of the digestive organs, or where the secretions are in a depraved state, without the previous use of means calculated to remove the former or correct the latter; to effect which, the employment of mild purgatives will in most instances be found best adapted. Tonics have a marked action on the various organs of secretion—their effects being to restore them to a healthy state. They are consequently administered with the view of diminishing secretion when it is excessive, or of restoring it when deficient, if either condition depend, as it frequently does, on inertia or want of tone in the secreting organ.' Independently of their tonic properties, some of the remedies contained in this class possess a specific power in ague and other periodical diseases; hence they have been denominated *Febrifuges.*

Few remedial agents are more largely employed at the present day than tonics and stomachics, not only for the purpose of renewing tone and strength where debility actually exists, but with the view of imparting additional vigour—hence the term *corroborants*—where the constitution is in ordinary condition. It is needless to say that the latter is altogether a mistaken notion; and that the best and safest of all corroborants are—proper dietary, clothing, exercise, cleanliness, freedom from harassing cares, and those general regulations insisted upon in the article PRESERVATION OF HEALTH. Were those regulations attended to as they ought to be, the class of remedial agents now under review might safely be swept from the lists of medicinal preparations.

Stimulants is the general term for remedies which excite sensation in the sentient parts, or motion in the muscular parts—in other words, any excitement of the vital energies. It is usual to distinguish them as *general* and *special*, according as they affect the whole system, or exert a peculiar influence on individual

organs or on the system generally. 'It is difficult, however, to define,' says Neligan—whose account of this class we shall adopt—'what is understood in the practice of medicine by the term Stimulant, excitement of the vital energies being produced by such different means under different circumstances. With no class of remedies, therefore, is it more necessary to bear in mind the truth of the maxim, that medicines act merely *relatively*. In their mode of action when administered internally, General Stimulants resemble in some respects Tonics; thus, immediately after their administration, a feeling of increased tone or power is produced, which, however, is not permanent, but is almost invariably followed by a corresponding depression of vital power; their effects also are more immediate, and more manifestly perceived by the senses, than those of Tonics. Many of them are also closely allied to Narcotics; for example, alcohol and the ethers, the secondary effect of both of which, particularly if given in large doses, is to produce sleep and coma. This does not, however, appear to be, as with Narcotics, from any direct action on the nervous system, but rather to result from the previous over-excitement of the vital energies. The great number of medicines contained in this class, and the material difference of their action in relation to the particular effects which they produce, preclude the laying down of any general rule for their administration.' The general stimulants usually enumerated are—alcohol, sulphuric ether, preparations of ammonia, camphorated acetic acid, camphor, anise, capsicum, ginger, cardamomum, caraway, cinnamon, oil of cassia, cocculus Indicus, lavender, mint, pepper, nutmegs, oil of turpentine, rosemary, sherry wine; and to these we may add electricity in its various developments.

With regard to Special Stimulants, 'many of them give rise to some alteration, which is not well understood, in the nature or quality of vital action, when they are called *Alteratives;* while others possess a special influence in the treatment of certain diseases, when they are denominated *Specifics*. Many alteratives and specifics have been already described in other classes of medicines, but the articles contained under this head cannot, with a regard to accuracy of arrangement, be included in any of them; inasmuch as the primary influence which some of them exercise on the animal economy has not been satisfactorily ascertained, and others possess a peculiar influence over *certain organs* or *diseases* merely. As examples of the former, we may refer to mercury, iodine, and gold; of the latter, to nux-vomica, cubebs, and copaiba.' The special stimulants commonly enumerated are—iodides and chlorides of gold, bromine, copaiba, cubebs, numerous preparations of mercury, iodine, iodide of potass, and some marine substances containing iodine; as sponge and cod-liver oil.

Under this section we have mentioned the therapeutical use of alcoholic liquors; and as much error seems to prevail on this matter, we shall here present in brief the opinions of Drs Christison, Pereira, Neligan, and other modern authorities. We avoid the testimony of the older medical schools, as having an evident bias to the employment of these agents; as much as we avoid the dogmas of those who would altogether discard them. Alcohol, in all its forms, is a highly valuable therapeutic agent. In moderate doses, properly diluted, it acts as a general stimulant, exciting particularly the vascular and nervous systems; in somewhat larger doses, it produces the well-known effects of intoxication; and in excessive doses, it acts as a powerful narcotic poison, rapidly causing death, preceded by slow pulse, contracted pupils, and coma. This effect is most usually observed when a large quantity of ardent spirits is swallowed at once, as for a wager. As a stimulant, alcohol is employed in medicine to support the vital powers in the advanced stages of fevers, particularly those of a typhoid character; for this purpose, brandy or whisky is usually employed, but wine is generally preferred. It is also often used as a household medicine in flatulent colic, in indigestion, in vomiting, and in fainting; but for these purposes it is a perilous remedy when resorted to frequently, because apt to lead to the vice of habitual over-indulgence. Mere alcohol is seldom used as a diuretic in regular practice; but it is a powerful and familiar remedy of the kind when united with certain essential oils, of which combinations the most esteemed is Hollands. As an external stimulant, it is a common ingredient in lotions for sprains and bruises, for many forms of external inflammations, as erysipelas and erythema, for various skin-diseases, to prevent excoriations in parts exposed to long pressure, and with friction over the region of the heart in syncope and suspended animation. In consequence of its producing cold by evaporation, alcohol is frequently added to cooling and evaporating lotions. Wines, we have said, are also used internally as stimulants, and for this purpose are often better suited than any other alcoholic liquid. Their use is particularly called for in the advanced stages of typhoid fevers, and where delirium is present, with much sinking of the vital powers. They are also given with advantage in convalescence from acute diseases, in chronic debility, especially when it is caused by excessive discharges, in mortification unaccompanied by inflammatory symptoms, and in tetanus or locked-jaw. When any local congestion or inflammation is present, or may be apprehended, the administration of wine in the treatment of disease is for the most part calculated to do mischief. Although sherry is the only wine officinal in the pharmacopœia, port is generally employed in medicine; claret and Madeira are also used. When its greater strength and astringency are not objectionable, port wine is always to be preferred. Madeira and claret are often inadmissible, on account of their acidity; but when this is not the case, the former is well adapted for persons of debilitated or broken-down habits, the latter when the employment of stronger wines might prove injurious. Sherry is chiefly employed in the preparation of medicated wines; but Cape wine, on account of its cheapness, is usually substituted by druggists. In a dietetical view (see BEVERAGES), sherry is the wine in most general use, and the one calculated to agree best with most constitutions.—Such are the opinions of medical authorities with regard to the medicinal or therapeutic uses of alcoholic liquids; and by their enlightened and unbiassed directions, ought unprofessional parties to be implicitly directed. The dietetic, habitual, or conventional employment of these beverages is altogether a different question.

Forms and Modes of Preparation of Medicines.

Some medicines are prepared in a liquid, others in a solid form, according as they may be soluble or insoluble, or according to the state in which it may be desirable to administer them. In general, the more finely a substance can be divided, the more rapidly is it taken up by the system, and the more instantaneous its effect; hence, instead of administering the crude vegetable or mineral, the necessity of preparing infusions, decoctions, tinctures, and the like. Another reason for adopting such preparations is, that the active or medicinal principle of a substance may constitute but a small portion of its bulk; while the greater portion may be of no value whatever, or may be even positively detrimental.

Infusions of vegetable substances are prepared by pouring boiling water upon the materials in a lightly covered vessel, and allowing it either to cool directly, or to continue at a gentle heat for a few hours; then straining, filtering, and bottling for use. In some cases cold water is preferable. *Decoctions* differ from infusions in being prepared by actual boiling of the substances;

and, if possible, in vessels of glass or earthenware. Decoction is apt to destroy the active principle of many vegetables. *Extracts*, which are much valued in pharmacy, are usually prepared by evaporating, to the consistence of a pill-mass, the expressed juices of plants, or their infusions or decoctions in water or spirits, at a temperature not exceeding 212°, by means of a vapour-bath, or by spontaneous evaporation in shallow vessels exposed to a current of air. *Tinctures* are solutions of vegetable, animal, or mineral substances, in some spirituous fluid—as proof-spirits, rectified spirits, and the like. *Sirups* are intended sometimes to cover the disagreeable taste of drugs, but more generally to preserve them in a convenient state for making mixtures, without the risk of their undergoing decomposition.

When medicines are administered in the solid state, one of the most common forms is that of *Powders*. Being in a state of fine division, powders act with considerable rapidity, and are administered in admixture with some fluid or conserve. *Pills* are regarded as the most convenient of all officinal forms, both for preservation and for administration; but in many instances not the most efficient in point of activity. The active ingredients of the pill are mixed with materials called Excipients, to give it the desired consistence. Bread-crumb is a convenient recipient for immediate use; but to make a pill that will not harden by being kept, conserve of red roses or of hips is considered the best. For preserving pills in a soft and active state, small bottles are much preferable to wooden boxes. According to Dr Christison, pills are usually made too large. 'Five-grain pills often pass through the body apparently but little altered; and it has occurred to me to observe that four colocynth and henbane pills, of one grain each, will operate as effectually as two five-grain pills, and more mildly.' *Lozenges* or *Troches* is another solid form in which drugs are now administered.

Cerates, *Ointments*, and *Liniments*, are preparations for external use, differing chiefly in their consistence—cerates being the firmest, ointments softer, and liniments softer still, or even liquid. As ointments are of use merely to protect wounds from their coverings, from the air, and from filth, the simpler they are the better. The same rules are to be observed in preparing *Plasters*, which have a similar basis spread equally on cloth, leather, or other tissue. *Poultices* are well-known external applications. They are described by Abernethy as of three kinds—the evaporating or local tepid bath, the greasy, and the irritating. The first is thus made: 'Scald out a basin, for you can never make a good poultice unless you have perfectly boiling water; then having put in some hot water, throw in coarsely crumbled bread, and cover it with a plate. When the bread has soaked up as much water as it will imbibe, drain off the remaining water, and there will be left a light pulp. Spread it, a third of an inch thick, on folded linen, and apply it when of the temperature of a warm bath.' The linseed-meal or greasy poultice is, on the same authority, to be made in the following manner: 'Get some linseed powder, not the common stuff, full of grit and sand. Scald out a basin; pour in some perfectly boiling water; throw in the powder, stir it round with a stick, till well incorporated; add a little more water, and a little more meal; stir again, and when it is about two-thirds of the consistence you wish it to be, beat it up with the blade of a knife till all the lumps are removed. Then take it out, lay it on a piece of soft linen, spread it the fourth of an inch thick, and as wide as will cover the whole inflamed part; put a bit of hog's-lard in the centre of it, and when it begins to melt, draw the edge of the knife lightly over, and grease the surface of the poultice.' The irritating poultice to be used in cases where a blister is unnecessary or inconvenient, is made simply of mustard and water, mixed as if for the dinner-table, and put within the folds of a piece of fine muslin, so that only the watery part, oozing through, touches the skin.

Mixtures and *Emulsions* are extempore preparations, of such strength, consistence, or quality, as each particular case may demand. The same may be said of *Fomentations*, which are warm fluids applied to the skin; and of *Lotions*, or washes, which are similarly applied either cold or warm. *Enemas*, or *Clysters*, are drugs administered in the form of injections; they vary in composition and volume according to the object to be effected.

In whatever form medicinal preparations may be administered, the quantity is invariably regulated by weight or by measure. Though differing in nomenclature and mode of subdivision, both of these are based on the imperial standard of the country. Thus the imperial pound Troy is divided into ounces, drachms, scruples, and grains; and the imperial gallon into pints, fluid ounces, fluid drachms, and minims. In detail—12 ounces make 1 pound, 8 drachms 1 ounce, 3 scruples 1 drachm, and 20 grains 1 scruple. Again, 8 pints make 1 gallon, 20 fluid ounces 1 pint, 8 fluid drachms 1 fluid ounce, and 60 minims 1 fluid drachm. The different denominations of weights and measures are denoted in the language of prescriptions by the following signs: Pound, ℔; ounce, ℥; drachm, ʒ; scruple, ℈; grain, gr.; Gallon, C; pint, O; fluid ounce, fl℥; fluid drachm, flʒ; and minim, m. Medical prescriptions are generally written in Latin, which, conjoined with these signs, Roman numerals, and a large amount of contractions, gives them a very formidable and mysterious aspect. Thus, ℞ (*Recipe*) *Nitratis Potassae* gr. xv.; *Aquae destillatae* fl℥iss; *Syrupi Limonum* flʒij. *M* (*Misce*). *Fiat haustus, ter in die sumendus*, is but the technical form of ordering the patient to 'Take fifteen grains of the nitrate of potass; one and a half fluid ounces of distilled water; and two fluid drachms of sirup of lemon. To mingle and form a drink of them, and take it three times a day.' Further, each university of importance has a list of medicinal preparations drawn up for the guidance of its own members and pupils, and this list is termed its *Pharmacopœia:* with the enumeration is given a full account of the processes by which the various substances are prepared for use. Thus London, Edinburgh, and Dublin have their respective Pharmacopœias; differing occasionally in particulars, but rarely or ever in essentials.

Medicine-taking.

The medicines most commonly employed at the present day for the alleviation or cure of disease have been now enumerated, in an arrangement which may shew their several properties and modes of operation. The information will have the effect, we humbly imagine, of dissipating some portion of that veil of mysticism which envelops the art of medicine, and of shewing what are the rational objects to be expected from the action of drugs upon the animal frame. There are at present two injurious opinions prevalent in the world on this subject, both of which are entertained alike by the ignorant and by the enlightened, and which are equally at variance with the truth, and noxious in their consequences. The first of these opinions is, that the science of medicine is from beginning to end a deception; that medical men are as much in the dark as their patients with regard to the cause and nature of disease, and are consequently quite unable to provide a remedy. Enlightened men are more liable, upon the whole, than the ignorant to imbibe this feeling of distrust. One of the most elegant writers of the day, for example, bitterly and satirically defines medicine to be 'the practice of pouring substances of which nothing is known, into bodies of which still less is known.' An opinion of this kind of course leads the person who holds it to regard the regular physician and the empiric as upon a level, and to look upon the prescriptions of the one as equally

contemptible, or, in other words, equally valuable, with those of the other. Those who hold this opinion, and indulge in sneers at what they do not comprehend, lose sight of the fact, that medicine is only one of many progressive sciences—its data being of a varying character, its conclusions must necessarily vary. The second opinion, which we alluded to as being prevalent in the world, is directly the reverse of the first, and is more common amongst the ignorant than amongst the intelligent part of mankind. It is a belief in the boundless powers of medicine, which leads those who entertain it to treat their bodies as if these had been designed by nature merely as receptacles for drugs. This opinion tends also to render those who hold it a prey to every successive nostrum that knavery and quackery can invent. It is based upon the very same foundation as the opposite opinion—namely, the mysticism that obscures the true objects and powers of medicine, for with some minds, whatever is dark and mysterious, becomes invested with supernatural qualities.

The persons who thus consider the art of medicine as unlimited in its powers, and believe that the body can never be in a proper state unless under the influence of some drug, are generally those who pore over all the medical books they can get hold of, and imagine themselves successively to be the subjects of every disease described. Finding an enumeration of remedies accompanying the descriptions of diseases in the books they read, they try medicine after medicine, till they impair their bodily powers, and create diseases where none originally existed. Sometimes this method of self-drugging and self-killing is varied by a mania, equally destructive, that leads them to the trial and use of all the pretended remedies which ignorant empirics foist so unremittingly on the world. Those knavish gentlemen, generally termed *quacks*, know thoroughly the points upon which the success of their gulling depends, and accordingly publish imaginary letters addressed to themselves, descriptive of cases in which their invaluable medicine, in the form of drops, pills, powders, or elixirs, 'has been of incalculable service.' These cases embrace every disease, and every symptom of disease, under the sun; and the infatuated beings who read and trust to them find always some fictitious case of cure, which appears to resemble their own complaint, and accordingly are deceived into the purchase of the 'invaluable medicine.' Were these quackeries simply impositions upon the credulous, the evil would not be so great; but exceedingly few of them have so much merit as to be innoxious. On the contrary, the records of the criminal courts tell a fearful tale of credulity, punished in many instances by death.

It is not with a view to increase the number of those who tamper, in the way described, with medicines that the preceding pages have been written. If such should be the consequence of the information they contain, no one would deplore it more sincerely than ourselves; but we confidently hope that, as far as their humble influence extends, the result will be very different. Those to whom the action of medicines on the system is a mystery, may fly to the quack for a nostrum, or try to discover one themselves; but those who have given the subject so much attention as to be aware that the action of medicinal substances on the body is as varied as the disorders which they are applied to remedy, and at the same time to a great extent demonstrable and intelligible—those who are possessed of this knowledge will scout the idea of a universal panacea, and despise the quack and his nostrums, while at the same time their confidence in the man who has devoted his days to the consideration and relief of disease will be increased tenfold, since they are assured that his objects and his plans are consonant to the soundest principles of true science, of reason, and of common sense.

We have just one word of advice to give in conclusion, and it is this: When any one feels himself afflicted with a complaint anyway beyond a very slight indisposition, let him at once, and without a moment's delay, send for a regular and skilful medical attendant, to whom let him communicate freely the state of his feelings, as well as what has been his previous course of life. The grand error in most people consists in 'putting off sending for the doctor' till it be too late.

Dr Combe says: 'Many mothers are continually administering medicines of one kind or another, and thereby deranging instead of promoting the healthy operation of the infant system. Instead of looking upon the animal economy as a mechanism constituted to work well under certain conditions, and having, in virtue of that constitution, a natural tendency to rectify any temporary aberrations under which it may suffer, provided the requisite conditions of action be fulfilled, they seem to regard it as a machine acting upon no fixed principles, and requiring now and then to be driven by some foreign impulse in the shape of medicine. Under this impression they are ever on the watch to see what *they can do* to keep it moving; and, altogether distrustful of the sufficiency of the Creator's arrangements, they no sooner observe a symptom, than they are ready with a remedy. Such persons never stop to inquire what the *cause* is—whether it has been, or can be, removed—or whether its removal will not of itself be sufficient to restore health. They jump at once to the fact that disease is there, and to a remedy for that fact. If the child is convulsed, they do not inquire whether the convulsions proceed from teething, indigestion, or worms, but forthwith administer a remedy *to check the convulsions;* and very probably the one used is inapplicable to the individual case; and both the disease and the cause being, in consequence, left in full operation, instead of being removed, the danger is increased. . . . . I have no hesitation in expressing my conviction that a child can encounter few greater dangers than that of being subjected to the discipline of a medicine-giving mother or nurse; and wherever a mother of a family is observed to be ready with the use of calomel, cordials, anodynes, and other active drugs, the chances are, that one-half of her children will be found to have passed to another world.'

SURGERY.

Nature, says Mr Lawrence, 'has connected the outside and the inside of the body so closely, that we can hardly say where one ends and the other begins.' It is therefore impossible exactly to define the boundary-line between medicine and surgery. Suffice it to say, that surgical diseases generally are those situated in parts of the body accessible to touch and to the direct application of remedies. Surgery, therefore, includes the treatment of the various injuries to which our bodies are constantly exposed in the daily occupations of life or from accidental circumstances. As most of those injuries occur when least expected, and when professional assistance is difficult to obtain, it is the duty of all men to inform themselves of the general principles upon which relief is afforded in cases of accident. We intend, therefore, to give a few leading directions suitable for cases of emergency—not by any means with the view of superseding the legitimate practitioner, but that in the interval which necessarily must elapse between the occurrence of the accident and the arrival of surgical assistance, the sufferer may be intelligently cared for; and that the surgeon may not, as too often happens, find his skill of no avail on his arrival, or have to use it to remedy the hurtful effects of ignorant interference. In country-houses, a medicine-chest should be kept, which may be obtained from any qualified druggist, and should contain some laudanum, chloroform, sal-volatile, quinine, and some of the simpler purgative medicines;

also some styptics, as gallic acid. Other drugs may be added as recommended by the medical practitioner of the neighbourhood. There should be a pair of scales for weighing out doses, and a graduated glass measure for fluids.

In the way of surgical appliances, there should be at hand some adhesive plaster, lint, simple spermaceti ointment, and a spatula for spreading it with; some roller bandages, three inches wide and eight yards long; scissors, a lancet, and a few surgical needles, which should be kept threaded with white silk, well waxed; a pair of forceps for taking up, and some fine twine or silk for tying, arteries.

BLEEDING.

Discharges of blood take place occasionally from nearly all the apertures of the body; and as they are frequently critical, or, in other words, the means employed by nature to relieve some local congestion, should not be checked, unless they threaten to induce a dangerous degree of exhaustion.

Bleeding from the nose may generally be checked by cold, by snuffing up powdered tannin, or, if that is not sufficient, by stopping the nostrils with little plugs of lint. It must be borne in mind, however, that the nostrils open behind into the upper part of the gullet, and that the blood may flow freely down the latter, though no longer appearing externally. If this be the case, the posterior nostrils, as they are called, must be plugged by a surgeon. If a person appears faint from loss of blood, he should be laid flat on his back; and if he can swallow, some stimulant—as wine or brandy—given him in small quantities. This should be done at once, as persons who have lost much blood are very liable to die from a sudden faintness or syncope.

Bleeding from wounds is either a general oozing from the surface, or from veins, when the blood flows in a continuous stream of a dark colour, or from arteries, when it is of a bright scarlet colour, and issues from the vessel in jerks. The oozing and venous bleeding will generally stop on the application of cold, pressure, or exposure to the air. The blood should not be allowed to coagulate in a wound, as the clot acts like a warm wet sponge, and encourages bleeding. Cut ends of arteries may be distinguished, by their remaining open, from those of veins, which collapse. An artery should be seized with the forceps, gently drawn out from the surrounding tissue, and tied with fine silk or twine; one end of the ligature should be cut away close to the knot, the other left in the wound, from which it may be gently pulled in two or three days.

If the artery be very small, a twist with the forceps may suffice, instead of the ligature; but if there be any doubt, the latter should be preferred. Veins should not be tied, as the inflammation of their coats necessarily produced by the ligature might be extremely hazardous to life. If the ends of the vessel are not easily reached, no attempt should be made to secure them till the arrival of a surgeon. In the meanwhile, the wound, or the main artery of the part, should be compressed; and it should be remembered that very slight pressure is sufficient, if properly applied; whereas, if exerted too energetically, the strongest thumb is soon wearied and useless. If there is a wound in the armpit, the handle of a door-key, with a turn of some cloth round it, may be pressed downward behind and above the middle of the collar-bone, so as to press the subclavian artery against the first rib. The thumb is scarcely powerful enough in such a case.

If the bleeding be very profuse, and attendance scanty, a tourniquet may be extemporised thus: A handkerchief should be passed a few times round the limb above the wound, and if the situation of the main artery is known, a pretty hard pad should be adjusted over it; the handkerchief should then be twisted sufficiently tight by means of a stick inserted between two of its turns. Direct pressure upon the artery, when efficiently applied, is, however, generally preferable to the tourniquet, which is very hurtful to the limb if left on too long.

Wounds are generally divided into cuts or *incised* wounds, and deep narrow stabs or *punctured* wounds, inflicted with sharp weapons; and into *contused* and *lacerated* wounds, when the injury has been accompanied, owing to the bluntness or roughness of the weapon, with bruising and tearing.

In an ordinary cut, the best practice is to bring the edges together, and wrap a piece of dry lint round the part. If there is any difficulty in keeping the cut surfaces in apposition, strips of plaster should be placed across the wound at intervals, or a few stitches, also at intervals; at each stitch the thread should be cut, and its ends tied in a common knot: this is called the *interrupted suture*, and is most commonly in use among surgeons. If recently cut surfaces are placed accurately in contact, they will, in all probability, reunite in a few hours by what is called *the first intention*. In wounds of the scalp, the surrounding surface should be shaved, and strapping applied in preference to stitches, as the latter are apt in some patients to induce erysipelatous inflammation. The orifices of punctured wounds should not be closed; and if inflicted with a dirty weapon, a poultice should be applied. Contused and lacerated wounds can hardly be expected to heal without undergoing some previous preparation; the portions of tissue which are much bruised will slough or die and separate; the surface of the wound will then be of a florid red, covered with minute fleshy elevations called *granulations;* these secrete a creamy fluid called *pus*, which protects them from the air, and must not be wiped off the surface of the sore. By degrees these granulations rise to the level of the surrounding skin, and then contract, drawing the margins of the sore nearer each other, and are converted into a tough non-elastic tissue called *cicatrix* or *scar*.

The best dressing for a healing wound is lint soaked in tepid water. If the healing action is languid, some stimulating ingredient may be added, as tincture of myrrh, in the proportion of a drachm to a pint of water; or the famous red lotion, which contains a grain of sulphate of zinc to an ounce of distilled water.

BURNS AND SCALDS.

When heat is applied to the surface of the body, either through a solid or fluid medium, the injuries produced will be almost alike, and their severity in proportion to the amount of caloric applied. Therefore, the directions for the treatment of scalds will be applicable also to burns; and those injuries may be divided into three classes:—1. Burns resulting in simple redness of the skin; 2. Burns resulting in vesication or blistering; 3. Burns resulting in sloughing, or death of the part. The first object, after the accident has occurred, is to relieve the suffering; and cold applied either in the form of ice or water seems in most cases to have almost a specific power in allaying pain and checking the advance of inflammation. In other cases, moderate warmth is found more efficacious, and we must be guided mainly by the sensations of the sufferer as to which of these remedies we make use of. In very severe cases, opium or chloroform may be employed. But if the injury the body has received be very serious, the patient complains less of pain than of cold; he shivers, is much depressed, and must be well supplied with stimulants to prevent his dying from shock.

The best local application is the Carron-oil, which derives its name from the famous ironworks, where it has been used for many years. It consists of equal parts of olive-oil and lime-water, and should be applied on linen rags or cotton-wool. Blisters may be pricked, and the contained serum allowed to trickle away, but on

no account is the raised skin to be removed. The dressings should not be changed oftener than cleanliness requires; and as each portion of the old dressing is removed, it must at once be replaced with fresh, so that as little exposure as possible of the burnt surface may take place. The main principle of treatment is exclusion of the air from the injured part; and so long as this is effected, it matters but little what remedial agent is employed. Great care must be taken in the treatment of a sore resulting from a burn, that the contraction of the scar does not cause distortion of the neighbouring parts.

When the clothes catch fire, the person should lie down on the floor, and roll herself, or be rolled, in the rug, table-cover, or anything sufficiently voluminous to stifle the flames; and afterwards the clothes, especially stockings, should be removed with great care, lest the cuticle should separate with them, which would materially increase the sufferings of the patient.

Extensive scalds or burns are very fatal to young children; and it must be remembered that their skin is more susceptible to external impressions, and will suffer from a degree of heat innocuous to an adult. Infants have frequently been scalded to death in too hot baths, or by too hot fomentations.

The principles of treatment for burns produced by the contact of chemical agents to the skin, are the same as those for burns by fire.

The symptoms produced by intense cold have a curious resemblance to those from intense heat. In this country, the most common effect is an inflammation of the skin called a *chilblain*. Chilblains are most commonly induced by sudden alternations of temperature, as when a person holds his cold toes too close to the fire. The treatment must depend on the severity of the inflammation; and after the latter has subsided, gentle stimulating applications, such as the soap liniment, or a liniment made by adding one ounce of mustard to a pint of turpentine; but care must be taken not to cause ulceration, as the sores arising under such circumstances are exceedingly troublesome and difficult to heal. When a part or the whole of the body has been exposed to severe cold, the surface appears pallid or yellowish white, and is insensible to touch. The living principle is lessened and feeble, and any sudden change of temperature would destroy the little that remains; so life must, as it were, be coaxed back by the gradual application of warmth. The part or whole body must be rubbed with snow or cold water, and as vitality returns, the cold media be gradually laid aside, and some warm tea, or wine and water, given internally.

INJURIES TO JOINTS.

The ends of bones entering into the formation of joints are covered with smooth gristle or cartilage, so that their motions upon each other may be smooth and unimpeded; and to insure this object, they have between them a bag of a thin tissue, called synovial membrane, which secretes synovia, or joint-oil, to lubricate the cartilaginous surfaces. They are bound to each other by strong white fibrous tissue, adjusted so as to keep those surfaces in their proper relations to each other, without impeding their movements. These fibrous bands are the ligaments.

A sprain consists in a wrench or strain of these ligaments. The synovial membrane which is in contact with them participates in the injury, and immediately inflaming, pours its fluid into the joint, causing swelling; which, confined by the surrounding fibrous structures, gives rise to great pain and constitutional disturbance. These symptoms vary in proportion to the severity of the injury. Rest and fomentations of hot water to the joint, and a dose of Dover's powder, followed by a purge, are usually sufficient. If the inflammation be very acute, and there is headache with quick pulse, half-a-dozen leeches should be applied, three on each side of the joint, in addition to the fomentations. No liniments should be made use of till the acute symptoms have passed away, when the soap liniment—the opodeldoc of the shops—will be found very efficacious.

A dislocation is when the surfaces of the bones forming a joint are displaced, and have no longer their proper relations to each other. The appearance of the joint is immediately altered, its movements limited, and accompanied by intense pain. The displacement may be partial or complete; it may be obvious to the most ignorant observer, or so obscure as to puzzle the most experienced surgeon. Soon after the occurrence of the injury, swelling takes place, accompanied by an increase of pain, and the constitutional symptoms of inflammation soon make their appearance. After the swelling has come on, it is generally very difficult to detect the nature of the injury, as the prominent points of bone can no longer be traced; therefore the sooner the surgeon is summoned the better, as the future usefulness of the limb will depend upon his treatment of it; and if dislocation has taken place, the longer its reduction is delayed, the more difficult will it be.

Fractures are of three kinds—*simple*, when the bone is broken; *compound*, when it is broken and a wound in the skin communicates with the fracture; *comminuted*, when it is broken into several small pieces. The symptoms are, great mobility, and a grating feeling when the bones are rubbed. Directly a bone is broken, the muscles contracting, displace the fragments. Here, as in dislocation, the chief obstacle to reduction is the muscular resistance. The surgeon must place the limb in the position which relaxes the muscles acting on the furthest fragment, and by gentle extension, bring the broken ends again in apposition; then he must fix them by adjusting some mechanical contrivance, as a splint of wood, pasteboard, or gutta-percha, properly padded, so as not to excoriate the skin, and fasten it to the limb with a few turns of a bandage. After a bone is once set, it should not be disturbed, but it is nevertheless desirable to ascertain the condition of the parts; therefore the bandage ought not to be carried over the seat of fracture; indeed, the less there is on the limb the better.

The symptoms of *fractured ribs* are generally to be gathered more from the feelings of the patient than from any direct evidence from grating or loss of form. On taking a deep inspiration, the patient feels acute pain at the seat of fracture. It is not of much consequence ascertaining the exact number of ribs fractured, and, moreover, the examination is extremely painful. A broad bandage should be rolled tightly round the chest, which, by fixing the ribs, and preventing the contractions of the muscles which lie between them, will give the patient much relief. The constitutional treatment must be to prevent the occurrence of inflammation within the chest. If the sharp broken end of a rib has been forced in, so as to tear the lung, the air is forced into the cellular tissue under the skin, and produces the condition called *emphysema*, which may be recognised by the puffiness and crackling upon pressure.

If the broken ends of a bone be kept at rest and in apposition, a few hours after the injury, inflammation occurs, and lymph is poured out around and between them, which becomes solid: it is called *provisional callus*, and forms a sort of natural splint. The substance interposed between the fractured ends becomes gradually converted into bone, and remains firm and strong, while the provisional callus, which forms an unsightly swelling, is absorbed, and the bone regains its former outline. In moving a fractured limb, it must be borne in mind that the sharp ends of the bones are lying among important soft parts, which may be easily lacerated by them; so the limb should be kept perfectly steady, and the patient moved with the greatest care. If a surgeon's advice can be obtained, no attempt

should be made at examination of the limb till his arrival; and unless absolutely necessary, no purgative medicines should be given, as they necessitate movement of the body, and consequently of the fractured leg; unless, indeed, the limb is swung—an improvement in modern surgery which cannot be too much recommended.

Fracture of the skull is generally very serious; frequently, though there is no fracture visible, there may be one through the base of the skull, which is almost always fatal, owing to the rupture of the large veins which take the blood back from the brain. These injuries are accompanied by symptoms classed under the heads of concussion and compression of the brain. Concussion, or stunning, occurs immediately on the receipt of the injury, and may be instantly fatal; or the patient, after lying a variable time, with his pupils often of different sizes, his skin cold, and his pulse weak and irregular, may recover consciousness, and be himself again; or gradually, owing to bleeding taking place within the skull, exhibit the terrible symptoms of compression of the brain, which are dilated pupils, unaffected by the brightest light, snoring, complete insensibility, and the cheeks flapping out at expiration. So complete is the paralysis, that the bladder no longer contracts to expel the urine which accumulates in it, and the muscles of the lower end of the bowel allow of the involuntary escape of its contents. If these symptoms depend upon the pressure of a piece of bone driven in upon the brain, the surgeon may elevate it by the operation of trephining; but if they depend upon effused blood, the patients rarely recover: children, however, rally after the most severe injuries, their elastic cranial bones gradually regaining their proper positions. In concussion, nothing should be done except removing the neckcloth, and leaving the patient *perfectly quiet;* and protecting him from the application of popular remedies—such as bleeding, pungent salts to the nose, or the administration of stimulants. Even after apparent recovery, careful watching is necessary, as it is for some days uncertain whether serious symptoms may not make their appearance. In accidents to the head, more perhaps than in any others, is passive obedience to the surgeon's directions absolutely necessary.

The symptoms produced by fractured spine vary according to the situation of the fracture. All the body below the injury, if the spinal marrow has been compressed, as generally happens, is paralysed; and if it be situated about the third vertebra in the neck, between the brain and the origin of the *phrenic* nerve, which supplies the diaphragm, the great muscle of respiration, death ensues very soon from suffocation. The attendants ought to remember that the paralysed parts are very susceptible of injury from heat, which to the healthy hand does not seem excessive; and, above all, should take care that the patient does not have the loathsome addition of a sore back to his other misfortunes. This depends upon the attendants, who must keep the sheets smooth, sponge the back with spirits and water, cover any inflamed spot with amadou (German tinder) or spongiopiline, and, if necessary, procure a water-bed.

POISONS.

By the word poisons, we mean any substance which, when applied to the body either externally or internally, has the power of producing effects deleterious to the animal economy. If a poison be swallowed, and we cannot get rid of it by emetics or the stomach-pump, we are obliged to administer other substances, which, by combining with the poison, may so alter its chemical properties as to render it innocuous. These latter remedies are called antidotes. We give a list of some of the most common poisons, arranged alphabetically for facility of reference.

The following extracts are made in a great measure from Thomson's *Conspectus of the Pharmacopœia:*

ACIDS.

Symptoms.—Great heat; burning pain in stomach; convulsions; death.

Antidote.—Magnesia; soap in water; after which the stomach should be emptied by the stomach-pump, or an emetic.

ARSENIC—A corrosive mineral poison.

Symptoms.—Metallic taste; spitting, nausea, and vomiting, which is occasionally mixed with blood; fainting and great heat at the throat; severe gripings, purging, and tenesmus, the stools being deep green or black, and horribly offensive; the urine scanty, red, and often bloody; palpitation of the heart; cold sweats; itching and swelling of the body; prostration of strength; paralysis of the feet and hands; delirium; convulsions; death.

Treatment.—Evacuate the stomach by the stomach-pump, using lime-water; administer large draughts of tepid sugar and water, chalk and water, or lime-water; avoid the use of alkalies, but administer charcoal and hydratic sesquioxide of iron; bleed freely; take a tepid bath, and use narcotics. If the fatal symptoms be averted, let the patient for a long time subsist wholly on farinaceous food, milk, and demulcents.

BLISTERING FLIES—An acrid animal poison.

Symptoms.—Nausea, vomiting, and purging; bloody and purulent matter; irritation of the bladder; pulse quick. If these symptoms be not soon relieved, they are followed by convulsions, tetanus, delirium, syncope, and death.

Treatment.—Bleeding; warm bath; opiate frictions; and clysters of mutton-broth and opium. Camphor applied both internally and externally.

CORROSIVE SUBLIMATE—A corrosive metallic poison.

Symptoms.—An acrid metallic taste, burning throat, salivation, nausea, and vomiting of blood; diarrhœa; tenesmus; the pulse small, quick, and hard; faintings; debility; difficult respiration; cold sweats; cramps of all the members; convulsions; and death.

Treatment.—White of egg, diluted in water, given in large doses; a mixture of soap and gluten of white flour; bleeding; warm bath; and to subsist upon broth, milk, and demulcent fluids entirely.

DEADLY NIGHTSHADE—An acro-narcotic vegetable poison.

Symptoms.—A sense of great dryness, and constriction of the pharynx; sickness; dilated pupils; dim sight; laughter; delirium; redness of the face; convulsions. The stomach becomes so paralysed, that vomiting cannot be produced, and death follows.

Treatment.—Give emetics of sulphate of zinc or copper; evacuate the bowels by purgatives and clysters; give large doses of vinegar and water; and after vomiting, strong coffee proves very efficacious.

FUNGUSES—Poisonous mushrooms, acro-narcotic vegetable poisons.

Symptoms.—Nausea, vomiting, and purging; cramp of the lower extremities; convulsions; an unquenchable thirst; delirium; coma; and death. The intellect remains entire to the last moment of life.

Treatment.—Three or four grains of tartar emetic; castor-oil; the lancet may be required. After the stomach is emptied, give small doses of ether in mucilage, diluted with vinegar. The debility must be treated with cinchona and other tonics, if a fatal issue is averted.

HEMLOCK—A narcotic vegetable poison.

Symptoms.—Sickness; difficulty of respiration; great anxiety; vertigo; delirium, which often rises to maniacal frenzy; dilatation of the pupils; stupor; trismus; convulsions; and death.

Treatment.—Evacuate the stomach by a scruple of sulphate of zinc, dissolved in an ounce of water; the affusion of cold water on the head; bleed freely; and administer vinegar and water, or any other acidulous liquid.

HENBANE—A narcotic vegetable poison.

Symptoms.—Sickness, stupor, dimness of sight, and delirium, followed by coma; dilatation of the pupils; the pulse is at first hard, but becomes gradually weaker and tremulous; petechiæ often make their appearance as the forerunners of death.

Treatment.—Evacuate the stomach by a powerful emetic; administer vinegar and acidulous drinks; but if the poison has already entered the system, bleed and purge frequently to stop inflammatory symptoms.

MONKSHOOD—An acro-narcotic poison.

Symptoms.—Vomiting; heat in the throat; attempts to swallow; perfect consciousness until just before death; debility; disordered vision; contracted pupil; bloody stools; collapse; generally no convulsions.

Treatment.—Evacuate the substance from the stomach, then administer freely acidulous fluids and cordials. External warmth; sinapisms.

MORPHIA.

Symptoms.—The acetate and hydrochlorate of morphia, in doses of three to six grains, cause headache, dimness of sight, vomiting, diarrhœa, costiveness, itching of skin, profuse sweats, convulsions, sometimes of an epileptic character. The acetate, in particular, causes tetanic twitching, generally terminating in death.

Treatment.—The same as in opium.

NUX-VOMICA (*Strychnia*)—An acro-narcotic vegetable poison.

Symptoms.—Sensation of inebriety; vertigo; tetanic twitchings; rigidity of the limbs and arms; extreme difficulty of respiration, with excruciating pain under the xiphoid cartilage; asphyxia, and death.

Treatment.—Evacuate the stomach and bowels, and then dilute freely with vinegar and water, and any other acidulous drinks.

OPIUM—A narcotic vegetable poison.

Symptoms.—Drowsiness and stupor, followed by delirium, pallid countenance, sighing, deep stertorous breathing, cold sweats, coma, and death.

Treatment.—Use the stomach-pump, or an emetic consisting of ʒss of zinc, and vomiting should be kept up by irritating the throat; use an astringent infusion instead of water with the stomach-pump. Give large draughts of vinegar and water, keeping awake the sufferer; a tepid bath; and dash cold water on the head, to rouse the sensibility.

OXALIC ACID—A corrosive poison.

Symptoms.—Burning pain in the stomach, nausea, and severe but ineffectual efforts to vomit; great dilatation of the pupils; vertigo, convulsions, and death.

Treatment.—Administer, as soon as possible, a mixture of chalk and water, then evacuate the oxalate of lime thus formed, by exciting vomiting, by copious dilution, and irritating the fauces.

PHOSPHORUS—A corrosive poison.

Symptoms.—Phosphorus, taken even in moderate doses, produces immediate death; and as it has been exhibited as a remedy, in this manner it may prove poisonous. The symptoms are violent pain of the stomach, with a hot taste in the mouth; great excitement of the arterial system, convulsions, followed by death.

Treatment.—Dilute largely, so as to fill the stomach with liquid, by which vomiting is produced without increasing the irritation of the viscus. Magnesia mixed with the fluid exhibited, is useful by neutralising phosphoric acid, which is formed in these cases.

PRUSSIC ACID—A sedative poison.

Symptoms.—If the dose is large, death is the immediate result; but if it does not exceed ten to twenty drops, it is followed by stupor, nausea, faintness, loss of sight, difficult respiration, dilated pupils, small pulse, syncope, terminating in death.

Treatment.—Chlorine water in doses of fʒij in f℥j of water; chlorine, largely diluted with air, inhaled; hot brandy and water, or camphor mixture, combined with liquid ammonia; oil of turpentine; cold affusion should be applied, and artificial respiration.

RATTLESNAKE POISON.

Symptoms.—Quick pulse; impeded respiration; sudden depression of strength in the wounded limb, extending over the whole body; convulsions; death. The wound becomes speedily gangrenous.

Treatment.—A ligature above the bitten part; suction of the wound; apply cupping-glasses; cauterise by hot irons or caustics. Administer internally eau de luce, ammonia, and olive-oil.

SULPHURIC ACID—A corrosive mineral poison.

Symptoms.—Austere taste in the mouth; heat in the throat and stomach; nausea; vomiting; horrible breath; the matter vomited tinged with both arterial and venous blood, and air-bubbles form on the spot if it fall upon marble or chalk; inflammation, and a cough resembling croup; concentrated irregular pulse; anxiety; convulsions of the face and lips. The intellect remains clear to the last moment of life.

Treatment.—Dilute instantly with milk mixed with calcined magnesia or soap, or fixed alkalies; and treat the secondary symptoms the same as in inflammation of the intestines.

TARTARIC ACID—A corrosive poison.

Symptoms.—Nearly the same as in poisoning by oxalic acid, but less severe.

Treatment.—Solutions of the alkalies, or chalk and water, and the secondary symptoms by bleeding.

Tartar Emetic—A corrosive mineral poison.

Symptoms.—Nausea; vomiting; hiccough; burning in the pit of the stomach; small, hard pulse; syncope; difficult respiration; vertigo; insensibility to external stimulants; cramps; prostration of strength; death.

Treatment.—Dilute with tepid infusion of galls, and evacuate by the stomach-pump; give large doses of yellow cinchona bark, to excite vomiting by their bulk.

Tobacco—A narcotic vegetable poison.

Symptoms.—Nausea; vomiting; headache; inebriety; sinking strength; cold sweats; tremor; convulsions; death.

Treatment.—Evacuate by three or four grains of tartar emetic; irritate the throat; give astringent fluids, tincture of yellow cinchona bark, or tincture of galls. Brandy, camphor, and cordials are useful.

Verdigris—A corrosive metallic poison.

Symptoms.—Dry, parched tongue; nausea; constant spitting; efforts to vomit; dragging at stomach; colic; griping; black stools; pulse hard and irregular; thirst; anxiety; cold sweats; cramps; convulsions, and death.

Treatment.—Large doses of syrup or sugar, albumen, and water, until the stomach is evacuated; then continue the albumen in moderate doses, combating inflammatory symptoms by bleeding.

DISEASES OF THE EYE.

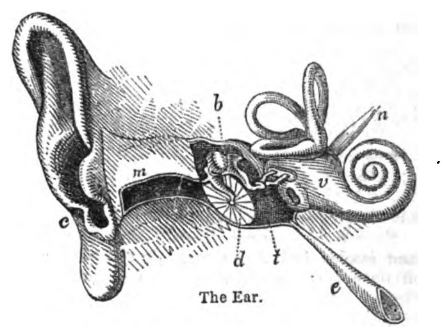
The eye is made up of so many different parts, each of which is subject to its own special maladies, that many surgeons, in different countries, devote themselves entirely to the study and practice of what is termed ophthalmic surgery. We do not intend entering fully into the subject, because its very nomenclature would be incomprehensible to the general reader; and the eye is of too great importance to be treated, except in simple cases, or under very peculiar circumstances, by an amateur practitioner. The most common affection of the eye is inflammation of the membrane which lines the insides of the eyelids and the front of the eyeball, the conjunctiva. Inflammation of this membrane is called *ophthalmia*. The symptoms of the simple form which is produced by some irritation either local or constitutional, or exposure to sudden changes of temperature, are, general redness of the eye, and fulness of the vessels; the patient becomes conscious that he *has* an eye, with a feeling as if dust were in it, and a strong inclination to rub the lids against the eyeball; there is also more or less intolerance of light. If these symptoms continue, there is a slight discharge of matter, and perhaps headache, with some degree of fever. The treatment must be varied according to the patient. If he be stout, and previously healthy, the bowels should be cleared with a dose of calomel, followed by a purgative draught; the eyes bathed with hot water, and shaded from the light: in severe cases, two or three leeches may be put upon the lower lid. If the patient be of a delicate constitution, all lowering remedies should be avoided. In both cases, after the acute stage has passed, astringent lotions may be used, and a few drops of a solution of nitrate of silver, or sulphate of copper, or sulphate of zinc, from the strength of gr. ij to f℥j of water upwards, may be put into the eye twice or thrice a day. When any foreign body finds its way between the eyelids, search ought to be made for it by inverting the lids; if it be sticking in the transparent cornea or the white of the eye, it must be picked out. If it be lime or mortar, the eye must be washed out as thoroughly as possible with vinegar and water, and a drop or two of castor-oil should be put into it. An overflow of tears may be caused by the passages through which they ought to flow into the nose being obstructed.

Squinting, or *strabismus*, is when the two eyes do not act in unison. Whatever may be the primary cause of this deformity, the agents are one or more of the muscles which move the eyeball. The treatment of squint ought to be, rest of the squinting eye, which is generally weaker than the other, and such remedies as tend to strengthen the constitution. When it appears evident that the squint is of a nature likely to be permanent, a surgeon should be employed to divide the faulty muscle, an operation easily accomplished, and one which ought not to be too long delayed, as the squinting eye, not being used so much as the sound one, becomes of a different focus, and otherwise less useful. Temporary squinting may be produced in children by irritation of the bowels from worms, or by teething.

A black eye, or ecchymosis from a blow on the eye, is merely inconvenient. If the effusion is great, it may be punctured, and allowed to bleed; but the only remedy is patience and fomentations with hot water.

THE EAR.

The ear is divided by anatomists into an external, middle, and internal ear. Each of these parts has its



The Ear.

own special diseases; and aural surgery has become of late years almost as complicated a subject as the surgery of the eye. We shall only allude to some of the commoner maladies; and we would warn our readers to beware of the many remedies which go under the name of 'cures for deafness,' and which can only benefit those who sell them. Some forms of deafness are very insidious in the outset, and many men continue to trifle with them until the sense of hearing is irrecoverably lost. The canal or meatus, marked *m* in diagram, which opens externally is about an inch long, and is formed partly of cartilage and partly of bone; the outer part is covered with small hairs, and has numerous sebaceous glands. The inner part has numerous ceruminous or wax-forming glands; this is the narrowest part of the passage. Accumulations of wax may be partially removed with a scoop, and then the passages should be syringed out with *clean warm water*. It is well, the night before syringing, to drop a little warm olive-oil into the ear. *Discharge of matter* from the ear may be the symptom of various diseases of the organ; it is most common in children during dentition, and it sometimes follows scarlet fever. A glance at the accompanying drawing will assist the reader to understand the discharge from the middle ear or tympanum, marked *b*, *d*, *t*, which is the most serious case, and is that kind usually following scarlet fever. It may be set up by inflammation extending from the throat up the Eustachian tube, *e* in diagram, which becomes closed by its thickened lining membrane. The matter secreted then accumulates in the cavity of the tympanum or drum of the ear, bursts through

the membrana tympani, *d*, and escapes externally at *c*. This may be caused by diseased bone in the ear, and sometimes is the result of meddlesome and ignorant doctoring. When a person, after an attack of fever, is about to become the subject of the last-described serious malady, he feels the pain which was previously confined to the throat extending into the ear. It becomes more acute and throbbing; he becomes deaf, has all the symptoms of high fever, including, perhaps, delirium; then a discharge begins to flow from the external ear, and the acute symptoms subside.

When these symptoms first set in, leeches should be applied behind the ear, and fomentations. The patient should be purged, and those remedies, such as mercury or antimony, which appear to have the power of subduing inflammation, should be given. When the fever subsides, the discharge must be washed out with warm water and white soap twice a day, a weak tepid astringent injection poured in, and then allowed to run out again.

Earache is the term generally applied to the pain which accompanies the diseases just described; but by medical men it is used to express neuralgia of the ear. It may be known from the former varieties by its suddenly coming on, and its always being of the same degree of severity; while the pain of *otitis*, or inflammation of the ear, increases in intensity, and is throbbing. The remedies for this affection are, removing causes of nervous irritation, such as decayed teeth, and giving tonics, especially quinine and iron.

As it is absolutely necessary that the membrane of a drum, to produce sounds, should have air on both sides, the Eustachian tubes are for the purpose of allowing air to pass up from the throat to the inner surface of the membrana tympani; so it is evident that when inflammatory swelling of their lining membrane renders them impervious to air, the tympanic cavity ceases to be a drum; hence deafness from cold, or what is called 'relaxed sore throat.'

THE NOSE.

When foreign bodies are put into the nose, attempts should be made to draw them forward, either with a bent probe or a forceps, opening the latter very wide, and closing it very gently. If these attempts at removal fail, it may be pushed back into the throat. Bleeding from the nose has been treated of under the head of Hemorrhage.

Nasal polypi are generally small pear-shaped gelatinous bodies, which produce a feeling of stuffing and cold, and prevent the patient from breathing through his nostrils. They must be gently pulled away by a forceps. There are other and more serious tumours which occasionally affect the nostrils.

Fetid discharge from the nostrils or ozæna is sometimes the result of catarrh in delicate subjects. The patient has all the symptoms of a cold in the head. Inhalation of the steam of hot water, into which twenty or thirty drops of creosote have been dropped, is the most efficient remedy, combined with tonics. In scrofulous subjects, there is sometimes ulceration of the nasal mucous membrane; and this, as well as disease of the nasal bones, may be the cause of a most offensive discharge, which must be washed out with a solution of chloride of lime in warm water, injected into the nostrils by means of a large syringe.

MOUTH, TEETH, AND GUMS.

Tongue-tie is when the frænum linguæ, or bridle of the tongue, ties that organ downwards to the lower jaw. This may prevent an infant from sucking. It may be lacerated with the finger-nail, or snipped with scissors. This is an operation frequently performed, and very rarely required.

The gums of infants are sometimes inflamed over a tooth which is about to come through; a lancet should then be carried along the gum, which, by allowing a flow of blood, and dividing the swollen tissues, relieves the tension, and consequent suffering.

If a tooth be dislocated, or driven quite out of the socket, and it happens to be a healthy one, it ought to be replaced, and tied to its neighbours by a silk thread.

In some persons, the enamel covering a tooth is imperfect, allowing the fluids in the mouth to exert a chemical influence upon it; the tooth so affected then becomes what is technically termed *carious*, and crumbles down, at last exposing the central cavity and its contained nervous pulp, which being affected by constitutional or other changes, produces *toothache*.

The treatment of carious teeth is either to protect the pulp with some artificial covering—as gutta-percha dissolved in chloroform—or the patient should consult a dentist, who will, if possible, put in some more permanent stuffing.

Toothache may be relieved by scarification of the gum near the affected tooth, and a small piece of cotton-wool dipped in mastic and tannin, a drachm of each dissolved in an ounce of water; to this a little powdered morphia may be added; or the central cavity may be touched with caustic of some kind. The victims of toothache inflict much unnecessary torture upon themselves by the application of toothache tinctures, creosote, &c. The saliva contains earthy matter in solution, which is sometimes deposited on the teeth, and is called *tartar*. It produces considerable irritation, if allowed to accumulate. To prevent this happening, care should be taken to clean the teeth well every morning and night with a tooth-brush and camphor-powder. Softening and tenderness of the gums greatly annoy some persons, who are generally suffering at the same time from disordered stomach or liver. The gums are very painful, bleed readily, and the teeth drop out. The constitutional symptoms should be attended to by purges and alteratives, the mouth daily washed out with astringent gargles; and if there is much soreness, some anodyne solution may be applied.

Gum-boil begins in the socket, or near a decayed tooth; and after giving severe pain, bursts externally. As soon as it comes near enough to the surface, it must be opened, and the tooth must be pulled.

EMERGENCIES.

Drowning, or suspended animation from immersion in water, is caused by the imperfect aëration of the blood in the lungs, not from the lungs filling with water; for so perfect is the mechanism about the upper part of the windpipe, that but a small quantity of water can find its way into the air-passages. The patient dies in the same state as one who has been hanged or exposed to the inhalation of carbonic acid gas; therefore, it is evident that the old plan of turning drowned persons upside down, or rolling them in a barrel, must be not only useless, but injurious. The period of submersion necessary to destroy life has not been exactly ascertained; but three minutes and a half are quite sufficient. However, the rule is, *always to make attempts at resuscitation*, and to persevere as long as the *least* hope remains of being successful.

When the drowned man is removed from the water, he is to all appearance dead, his face livid, lips blue, jaws firmly closed, a viscid froth issuing from the nostrils, and his body is swollen. If a house be within reach, he should be taken there at once, carried carefully with the head higher than the shoulders, and a messenger should be sent on to prepare a bed, warm bath, &c. But if the accident take place at a distance from such conveniences, he should at once be stripped and dried with the clothes of the bystanders, if nothing else is at hand; and then the 'ready method,' as it is named by its inventor, Dr Marshall Hall, should be tried thus:

Lay the patient's left arm across his chest; hold his mouth open, and pull the tongue forward. Then let one

at his shoulders and another at his legs turn him over towards his left side; when *almost* over on his face, roll him back again; and so on from right to left. Dr Hall has shewn that by this movement of the body the natural respiratory efforts are more efficiently imitated than by inflating the lungs with the bellows, the mouth, or by forcibly compressing the walls of the chest; and since the publication of Dr Marshall Hall's experiments on the subject, many apparently hopeless cases have been successfully treated.

When the drowned person is brought to a house, all unnecessary attendants should be requested to withdraw. He should be then placed in a warm bath; and artificial respiration, by compressing the walls of the chest, and then allowing them to expand, should be tried repeatedly and vigorously. The sheets should be stripped off a bed, and he should be laid between the blankets, with hot bottles or bricks to the soles of the feet and armpits; the whole surface of the body should be rubbed with flannel, especially over the region of the heart. The mucus should be wiped from the nose and lips; and any one present may put his mouth to that of the drowned man, press the windpipe—Adam's apple—back against the gullet with one hand, and blow into the mouth; if the windpipe be not pressed back, the air will go into the stomach instead of the lungs.

All these efforts must be continued. Galvanism, if possible, should be tried, and the rubbing persevered in for hours. Dr Douglas has published a case in which the patient was submerged fourteen minutes, and shewed no signs of vitality till the efforts at revival had been continued for eight hours and a half. If these efforts are successful, there will be seen a short convulsive effort to breathe, repeated in a few minutes; then the heart begins to beat feebly, and respiration and circulation are gradually restored. A very little warm stimulant should now be given, care being taken that it does not pass into the windpipe.

The patient should now be carefully watched: he may at once come to himself, or may remain semi-delirious, and imagine himself still in the water. If there is much sleepiness or tendency to relapse into insensibility, he ought to be cupped at the back of the neck, to relieve the congested state of the brain.

Suffocation from Foul Air.

Carbonic acid gas, if undiluted with common air, produces spasm of the glottis or upper part of the windpipe, which closes to prevent the poison entering the lungs. It is generally found in brewers' vats and cellars. A person entering a vat sometimes drops suddenly to the ground from the effect of this gas, and, unless rapidly removed into a purer atmosphere, will undoubtedly die. He must be dragged out with grappling-irons, or some one with strength and courage may rush in and drag him out.

Remedies.—Strip the body; dash cold water on the face and chest; rub hartshorn and oil over the chest; use artificial respiration. If the surface of the body be cold, apply hot bottles, &c., to the feet; try to induce vomiting by tickling the throat. If within reach of an infirmary, take him there, and further attempts may be made with electricity and the inhalation of oxygen gas.

The air of a room may be rendered poisonous by burning charcoal in it; the slower the charcoal burns, the more carbonic acid gas is evolved, till at last any person who may be in the room becomes motionless, speechless, and insensible, dying at last in a state of stupor. Burning common coals also may generate sufficient carbonic acid gas to destroy life, if there is no chimney to the room.

Sulphuretted hydrogen is generated in drains, sewers, cesspools, &c. If breathed by itself, it at once produces unconsciousness and death. If mixed with common air, it produces vomiting and headache.

Treatment.—Removal into fresh air; artificial respiration; then stimulants, as brandy and water.

Strangulation.

The person strangled is in the same condition as the drowned man. Death, except when it has been inflicted by the professional hangmen, who generally break the neck, has resulted from the inability to receive *fresh air* into the lungs. The countenance is swollen and purple, the eyes staring open, the mouth frothy and open, and the tongue protruding, the hands clenched, and the tips of the fingers blue.

Strip the body, dash cold water on the face and chest; use the methods of artificial respiration as in drowning, and bleed from the arm or external jugular vein.

Choking.

Occasionally persons are choked by foreign bodies getting into the upper part of the throat, and so blocking up the aperture of the windpipe. It is astonishing what masses of food a hungry man will attempt to swallow, which, in their passage down the gullet, sometimes produce pain, which lasts some minutes, and is soonest remedied by large draughts of water. Sometimes a fish or rabbit bone scratches the lining membrane of the gullet, and leaves a distressing sensation of something sticking in the passage, the patient occasionally becoming very nervous and anxious, making violent attempts to get rid of it by swallowing bits of bread, drinking water, &c. If a surgeon be at hand, he should pass a whalebone *probang*, with a bit of soft sponge at its end, down the throat. In performing this operation, care must be taken not to pass it into the windpipe. Before using more severe methods, the finger ought to be passed as far as it will reach, to search for the foreign body, and hook it out.

When immediate suffocation is threatened, an opening should be made into the windpipe, which consists of an upper part or box, called the *larynx;* a middle long portion, formed of imperfect rings, the *trachea;* and the subdivisions of the latter after it has passed into the chest, one on each side, the *bronchi.* For foreign bodies in the upper part of the larynx, it is sufficient to make an opening into it just below the obstruction. This is called laryngotomy, and may be performed by any one with any cutting instrument. The urgency of the case does not allow time for surgical assistance to arrive; and many a man has died from want of the following simple proceeding:

Laryngotomy.—Pull the head back; run your finger from under the chin down the middle line of the neck. You will first feel the hyoid bone, then a depression, then the hard prominence of the thyroid cartilage, or Adam's apple; then the finger will sink into the space between the thyroid and circoid cartilages, which is occupied by a tense membrane, into which plunge a penknife, and insert a bit of the quill of a pen. If the bleeding is considerable, enlarge the skin-wound, and take up and tie the artery, which is a small one running across the membrane. Then send for a surgeon, who will conduct the after-treatment.

Tracheotomy is a more severe operation, which is simple to the anatomist, but would be full of hazard to the patient if attempted by the hands of an amateur.

THE SKIN.

When a papilla of the skin increases in size, and is covered by an unusual quantity of the scarf-skin, or cuticle, which is also sometimes hardened, the little tumour thus formed is called a *wart.* When these enlarged papillæ occur in some part of the body where they are kept constantly moistened by perspiration, their covering of scarf-skin is very thin, they are apt to bleed, and sometimes have a thin yellowish discharge.

Warts on the fingers may be snipped off, or tied with a thread round the base, or touched with caustic; they

often disappear without any surgical interference. The others should be frequently washed, and some astringent lotion applied, or be snipped off by a surgeon. Sometimes in old persons a warty growth appears on the face, which, though simple originally, may become cancerous; and the person should at once consult a surgeon.

Corns are produced by some local irritation causing an unusual growth of thick scarf-skin, and are generally found over projecting portions of bone on the toes or soles of the feet, or any part where the skin undergoes pressure.

Wash the feet in warm water. Put some soothing plaster over the corn, or a piece of thick leather with a hole punched to correspond to the corn, and so relieve the pressure. Pare the latter frequently, and wear easy shoes.

Soft corns are small irritable growths from the true skin found between the toes, and should be touched with *nitrate of silver*. When a hard corn is much irritated, the skin at its base inflames, and some matter is formed, which produces intense suffering. The corn ought to be pared down to the matter, which will give instant relief.

Boils are little hard painful swellings in the true skin, which come sometimes from too good living, at others, from too low a state of health, and at some seasons are epidemic. They should be poulticed at first, when a little slough will come away in a few days; it is better, however, to have them lanced after suppuration has once set in. Alterative medicines should be given; and to prevent their recurrence, some alkali, as a teaspoonful liquor potassæ twice a day, or soda in milk, should be taken.

ANÆSTHESIA.

Within the last few years, a great change has taken place in operative surgery, and in the treatment of all diseases accompanied by acute pain, from the introduction into general use of anæsthetics, or substances which have the power of inducing insensibility to painful impressions without injuring the constitution.

The idea of painless operations is an old one. The writers of the Augustan age mention that before the hot-iron cautery was applied, the patients were given wine, with the root of the mandragora soaked in it; and that while under the influence of this mixture, they might be cut or burned without pain. In the thirteenth century, narcotic vapours were employed to induce insensibility to surgical operations; but these humane remedies fell into disuse. In 1784, a Mr Moore in London tried the effect of pressure on the principal nerves of a limb, and in one or two instances operations were performed on limbs so treated with but little suffering; however, the pressure on the nerves was in itself so intensely painful, that it was soon given up.

After the discovery of nitrous oxide, many experiments were made; and Sir Humphry Davy suggested that it might be found serviceable in making patients insensible to the surgeon's knife. Mr Horace Wells, a dentist in America, acted upon this hint in 1844, and when under the influence of the nitrous oxide, had one of his own teeth pulled. He subsequently administered it to some of his patients, and extracted their teeth without their being conscious of the slightest pain. Wells then went to Boston to exhibit before the medical faculty; and his experiments having unfortunately failed, he was laughed out of his profession, and committed suicide in January 1844.

His pupil, Morton, who had assisted in the experiments with nitrous oxide, settled in Boston as a dentist; and in connection with Dr Jackson, endeavoured to find some means of extracting teeth without pain. They seem to have been led to try sulphuric ether, by remarking that its vapour was used as a remedy for spasmodic affections of the chest. Morton inhaled it himself on the 30th of September 1846, from a tube communicating with a flask containing the ether; and thus he is undoubtedly the discoverer of a manageable method of administering its vapour. No sooner was he awake after this first inhalation than he longed to try it on some one else, and offered five dollars to any one who would allow him to pull a tooth.

While he was anxiously waiting for a patient, Eben Frost, a nervous, frightened man, came into his surgery wanting a tooth pulled, but begged to be mesmerised, as he dreaded the pain. He was persuaded to inhale ether, became unconscious, and remained so while Mr Morton extracted a large double tooth. This case, which occurred at 19 Tremont's Row, Boston, on the 30th of September 1846, is the first in the modern era of anæsthesia in surgery.

The news having arrived in England, that great surgeon, the late Mr Liston, on the 21st of December 1846, administered ether to a patient in University College Hospital, in London, and removed the toe-nail, a most painful operation. Mr Liston's example was soon followed by Mr Fergusson, in the King's College Hospital; and surgeons in all parts of the kingdom soon made trials of it.

But the reign of sulphuric ether as an anæsthetic was doomed to be a short one; for, on the 4th of November 1847, Professor Simpson of Edinburgh discovered the anæsthetic powers of chloroform.

This is a heavy colourless fluid, which was discovered by Soubeiran in 1831. It is obtained by distilling rectified spirit with water and chloride of lime, has a specific gravity of 1·497, and boils at 140°. It has a pleasant fruity smell, and is now so well known, that further description is unnecessary.

The best way to administer chloroform is from a handkerchief; and attention should not so much be paid to the quantity administered, as to the symptoms produced. When insensibility is complete, the eyeball may be touched without winking, and the muscles are relaxed. This state should be kept up by occasional inhalations, but care must be taken not to let it be more profound, lest the patient get into a state of coma, and his life be in danger. No food should be taken for a few hours before inhaling chloroform. Non-professional persons should not, as a general rule, give chloroform to themselves or others, as, like every other remedy, it may do harm when unskilfully administered. Some persons are hysterical under its influence, but that soon passes off, and there is seldom any unpleasant sensation experienced upon waking, but generally one of wonder and thankfulness. Operations can now be performed under its influence in almost all cases where operations are themselves justifiable. Delicate patients are spared the shock and alarm of the operation; and children, instead of being, as formerly, mad with terror, now lie in a quiet sleep; and not only is the patient benefited by being spared suffering, but the operator can perform the various steps of the operation more leisurely and satisfactorily than he could during the struggles and cries of his subject, however great his nerve or experience in the use of the knife might have been.

In some few cases, intense cold may be applied to the surface of the skin through which the knife is to pass. Dr Arnott uses a mixture of pounded ice and salt.

Mesmerism has not found many advocates among medical men, for though it is certain that occasionally a person is met with who is susceptible to the influence of the mesmeric passes, still the majority of Europeans are happily too sound in mind and body to allow of mesmerism being of general use for the relief of pain; and it is scarcely desirable that persons should be brought into a state of hysterical catalepsy when they can safely and speedily be thrown into a profound sleep by the inhalation of chloroform.

CLOTHING—COSTUME.

WHETHER inhabiting a tropical, temperate, or arctic region—existing in abject barbarism, or enjoying the highest degree of civilisation and refinement, man is essentially a clothing animal. *Some* kind of covering or decorative appendage he always affects, being instigated to this necessity by motives of defence, shelter, decorum, or vanity. From the simple head-dress and loin-cloth of the South-sea islander, to the elaborate costume of the gay Parisian, the ruling principle is much the same; more rational, perhaps, in the case of the savage than in that of the individual laying claim to superior enlightenment. In obeying this clothing instinct or necessity, attention is always paid, not only to the kind and quality of the covering, but to the form and manner in which any particular article of dress shall be worn. Thus originates the distinction between clothing and costume—the one having reference to the fitness of the material for the purposes of shelter or protection, the other having reference to taste or a sense of the becoming, though often marred by the absurdities of vanity and caprice.

CLOTHING.

Admitting the above distinction, and laying aside consideration of all dress or armour of a defensive kind, clothing must be regarded simply in the light of a protection from the extremes of heat and cold, so that the body may perform its functions healthfully and without obstruction. Keeping this purpose in view, and also bearing in mind the nature and action of the human skin (see No. 8), 'it is easy to deduce that clothing should be of such a nature as not to impede the necessary escape of perspirable matter, but to suffer it to pass through its texture; that it should be of such a non-conducting quality as to confine the heat generated by the blood sufficiently to preserve the activity of the nervous system; and that, by its lightness, softness, and pliancy, it should permit the free motion of the limbs.' Clothing which would subserve all these purposes, would be nearly perfect in its hygienic properties; and such an attire we could readily assume, were it not that considerations of economy, special avocations, and the like, are always interfering less or more to disturb the equilibrium. With these preliminary remarks, and referring the reader for further information on the general hygiène of dress to the article PRESERVATION OF HEALTH, we shall now consider the peculiar characteristics of British clothing.

Quality of Clothing.

Woollen fabrics, as articles of clothing, have several advantages over other materials. They are bad conductors of heat; hence their warmth by preventing the heat of the body from escaping, and their utility in preserving the equability of its temperature, though exposed to sudden changes. From their filamentous texture and elasticity, they are light and pliable; and yet, from their peculiar property of being *felted*, they can be prepared to any degree of weight and thickness. They possess also the property of not being easily wetted, while they are sufficiently porous either to absorb or to permit the escape of all cutaneous exhalations. Further, when worn next the skin, their rough and uneven surface produces in every motion of the body a gentle friction, which greatly assists and promotes the functions of the minute cutaneous vessels and nerves. 'In a climate like ours, which is so variable, and usually so cold, the article of dress that is worn next the skin ought always,' says Dr Robertson of Buxton, 'to be a bad conductor of heat at all events. In general, flannel of an adjusted degree of thickness and fineness answers this intention sufficiently well, without proving to be too heating, or irritating, or relaxing. In summer-time, if the flannel which proved to be well borne in the colder seasons of the year, should be so far irritating and heating as to relax or fever the system, this may be remedied by substituting for it a thinner and finer quality of flannel; or in extreme cases of this kind, an under-garment of calico, of a proper degree of thickness, may be substituted for the flannel at that season of the year.' The use of chamois leather as the under-garment is objectionable.

But, strongly as the importance of having a bad conductor of heat next the skin should be impressed on the mind, there is a point connected with it which is almost as important. The inner garment, especially if made of flannel, ought not to be worn during night. It ought invariably to be taken off at night, and as invariably

resumed in the morning. In bed, it is unnecessary: it is worse than unnecessary, for it does harm: it then stimulates the skin, and produces a preternatural waste of the secretions, and corresponding debility of system —a corresponding liability to suffer from the depressing influence of cold—a corresponding incapability of resisting its influence. But, further, removing this garment during the night relieves it from the scurf, some degree of dampness, and other impurities which it must acquire during a day's wear, and so renders it fresh and more agreeable to the sensations of the wearer. Not wearing it at night renders it more effectual in protecting the surface from the cold by day, on the principle that a great-coat is not of the same service to the wearer when out of doors, if he is in the habit of wearing it in the house. It would be easy to adduce strong evidence in behalf of the value and importance of wearing flannel next the skin. 'Sir John Pringle,' says Dr Hodgkin, 'who accompanied our army into the north at the time of the Rebellion, relates that the health of the soldiers was greatly promoted by their wearing flannel waistcoats, with which they had been supplied on their march by some Society of Friends;' and Sir George Ballingall, in his lectures on military surgery, adduces the testimony of Sir James Macgrigor to the statement that in the Peninsula the best-clothed regiments were generally the most healthy; adding that, when in India, he witnessed a remarkable proof of the usefulness of flannel in checking the progress of the most aggravated form of dysentery in the second battalion of the Royals. Captain Murray told Dr Combe that 'he was so strongly impressed, from former experience, with a sense of the efficacy of the protection afforded by the constant use of flannel next the skin, that when, on his arrival in England, in December 1823, after two years' service amid the icebergs on the coast of Labrador, the ship was ordered to sail immediately for the West Indies, he ordered the purser to draw two extra flannel shirts and pairs of drawers for each man, and instituted a regular daily inspection to see that they were worn. These precautions were followed by the happiest results. He proceeded to his station with a crew of 150 men; visited almost every island in the West Indies, and many of the ports of the Gulf of Mexico; and, notwithstanding the sudden transition from extreme climates, returned to England without the loss of a single man, or having any sick on board on his arrival. It would be going too far to ascribe this excellent state of health solely to the use of flannel; but there can be little doubt that the latter was an important element in Captain Murray's success.'

There can be no doubt that flannel is by much the best article for being worn next the skin when the body has to be exposed to such a temperature, or to such a severe degree of exercise, as increases the perspiration in a material degree. The common practice among the workmen in potteries, foundries, collieries, &c., of wearing thick flannel shirts, tends much to preserve their health, under the circumstance of the profuse perspiration caused by the excessive labour they are called upon to undergo, or the extreme heat of their places of work, alternated as this must be with the much colder atmosphere out of doors, amounting, it may be, to a difference of temperature of no less than 60° or 70°. Dr Kilgour, in his *Lectures on Therapeutics and Hygiène*, says 'that the use of flannel was found to be beneficial in the prevention of cholera, by maintaining the equilibrium of the temperature and the functions of the skin, and thereby preventing that derangement of the bowels which is so general a consequence of cold applied to the surface.' To the preceding excellent testimony, we may add that woollen fabrics, from their ready elasticity, are less liable than any other species of clothing to interfere with the circulation of the vital fluids, or prevent the free and easy motion of the body.

Cotton, though greatly inferior, ranks next to wool in non-conducting properties. From its comparative cheapness, lightness, and the facility with which it can be cleaned, it has of late years been gradually superseding the use of flannel as an underclothing. But, though recommending itself for these reasons, it can by no means be considered as a perfect substitute for flannel, whether used in a pure state or when mixed with a certain proportion of wool. Its ultimate fibre is altogether different; being void of that springy softness and elasticity so peculiar to wool, and incapable, moreover, of being felted to any thickness without becoming hard, heavy, and obstructive. Further, it is far from being so absorbent, is more readily wetted, and requires therefore to be more frequently changed and submitted to the laundress. Nevertheless, it is a valuable staple of dress, and is in general use both as under and exterior clothing from the tropics, of which it is a native produce, to the limits of the polar circle.

We have said that cotton is inferior in its non-conducting properties to wool—that is, all things being equal, cotton fabrics form a cooler dress than those of woollen. These remarks apply to our own climate; let us hear the opinion of the authority already quoted in reference to the requirements of tropical regions:— 'Cotton, from its slowness as a conductor of heat, is admirably adapted for the tropics. It must be recollected that the temperature of the atmosphere, in the open air, in the hot season, exceeds that of the blood by many degrees; and even in the shade it too often equals, or rises above, the heat of the body's surface. Here, then, we have a covering which is *cooler* than linen; inasmuch as it conducts more slowly the *excess* of external heat *to* our bodies. But this is not the only advantage, though a great one. When a *vicissitude* takes place, and the atmospherical temperature sinks suddenly far below that of the body, the cotton, still faithful to its trust, abstracts more slowly the heat *from* our bodies, and thus preserves a more steady equilibrium there. To all these must be added the comparative facility with which it absorbs the perspiration; while linen would feel quite wet, and, during the exposure to a breeze under such circumstances, would often occasion a shiver, and be followed by dangerous consequences. That woollen and cotton should be *warmer* than linen in low temperatures will be readily granted; but that they should be *cooler* in high temperatures will probably be much doubted. If the following easy experiment be tried, the result will decide the point in question:—Let two beds be placed in the same room at Madras, we shall say when the thermometer stands at 90°, and let one be covered with a pair of blankets, the other with a pair of linen sheets, during the day. On removing both covers in the evening, the bed on which were placed the blankets will be found *cool* and pleasant, the other, uncomfortably warm. The reason is obvious. The linen readily transmitted the heat of the atmosphere to all parts of the subjacent bed; the woollen, on the contrary, as a non-conductor, prevented the bed from acquiring the atmospherical range of temperature, simply by obstructing the transmission of heat from without. This experiment not only proves the position, but furnishes us with a grateful and salutary luxury, free of trouble or expense.

'From this view of the subject, *flannel* might be supposed superior to *cotton;* and indeed at certain seasons, in particular places—for instance, Ceylon, Bombay, and Canton—where the mercury often takes a wider range in a very short space of time, the *former* is a safer covering than the latter, and is adopted by many experienced and seasoned Europeans. But in general the use of flannel in the tropics is inconvenient for three reasons:—1. It is too heavy—an insuperable objection; 2. When the temperature of the atmosphere ranges pretty steadily a little below that of the skin, the flannel is much too *slow* a conductor of heat *from*

the body; 3. The spiculæ of flannel prove too irritating, and *increase* the action of the perspiratory vessels on the surface, when our great object is to *moderate* that process. From the second and third objections, indeed, even cotton or calico is not quite free, unless of a fine fabric, when its good qualities far counterbalance any inconvenience in the above respects. In some of the upper provinces of Bengal, when the summer is intensely hot and the winter sharp, the dress of the native shepherds, who are exposed to all weathers, consists in a blanket, gathered in at one end, which goes over the head, the rest hanging down on all sides like a cloak. This answers the triple purpose of a *chattah* in summer to *keep out* the heat, of a tent in the rainy season to throw off the wet, and of a coat in the winter to defend the body from the piercing cold.' To this may be added, that no tropical head-dress can compete, in point of comfort and safety, with the loose, light-coloured turban of calico.

Linen, though inferior both to cotton and wool as a non-conductor of heat, and absorbent of moisture, is now extensively used as an article of inner clothing. In this capacity it has been of essential service to personal cleanliness, rendering the bath less necessary in modern Europe than in any other region of the globe. It is comparatively cheap, is easily kept clean, and its snowy whiteness enables us at once to detect when it is soiled or unfit for wear. It has been said by some one in jest, that 'a change of linen is a luxury;' and really so it is when well washed, bleached, and dried under the open air. There is a freshness and positive feeling of comfort about it not to be found in any other fabric however costly or fine. On the other hand, it must be confessed that linen has many disadvantages as an article of inner clothing. Being denser in the fibre than cotton, and much more so than wool, it forms a good conductor of heat, and thus rapidly robs the skin of its free caloric; hence the cold feeling experienced when linen is just put on. But though rapidly conducting the heat, it has little capacity for moisture, and thus soon becomes saturated, leaving the pores of the skin clogged and obstructed, unless the garment be frequently changed. Having little elasticity of fibre, it forms a smooth and dense fabric, totally void of that stimulating function often so much valued in flannel. From the experiments of Count Rumford, it appears that linen does not attract dampness so readily as wool, hair, or other animal substances; nevertheless, when it is damp, it is more prejudicial than these, and therefore requires to be well dried and aired before being worn.

Silk, as a non-conductor of heat, ranks next to cotton; but its qualities in this respect depend in a great measure upon the kind of fabric into which it is woven. Generally speaking, silken fabrics are light and thin; articles of luxury and ornament rather than of everyday utility. Nevertheless, silk possesses several valuable hygienic properties, of which the most curious and least understood is that appertaining to its electric qualities. It is found (see No. 17), that on the whole the state of the body when healthy and vigorous is *positive*, or that a surplus of positive electricity tends always to appear on the surface, from the actions of the vital organs; but that, after severe labour, hard exercise, and exhaustion, the state of the free electricity generally changes to *negative*. It is not improbable that when the actions of electricity on the animal system are better understood, it may be possible to use artificial methods of maintaining, under all circumstances, the charge that is identical with health and activity: we have acquired, by means of our houses, clothing, and fires, an almost perfect command of the element of heat; and it is to be hoped that we may some day attain an equal command over the element of electricity, and keep at a distance the deleterious negative charge as effectually as we defy the winter cold. On this important subject, so far as the influence of silk—which is an excellent non-conductor of electricity—is concerned, Drs Robertson and Carpenter have the following interesting remarks, which we transcribe at length:

'However little or unsatisfactory our knowledge of the operations of this remarkable agent in the animal economy, there is no doubt that electricity fulfils important and necessary purposes in the living system, and that a certain amount of positive or negative electricity is being constantly given off from the surface of the body in greater or less degree, according to sex, temperament, weather, the nature of the clothing, &c. It has been said that the skin and most of the internal membranes are in opposite electrical conditions; and, according to a theory of Dr Wollaston, the existence of free acid in the urine and gastric juice marks the prevalence of positive electricity in the kidneys and the stomach; whereas the existence of free alkali in the bile and the saliva indicates an excess of negative electricity in the liver and the salivary glands. Whether this view be tenable or not, it seems that the living body is never in a state of perfect electrical equilibrium with the substances or bodies around it, unless it be maintained by free contact with them; and it is stated, in illustration of this, that if two persons, both insulated, join hands, sufficient electricity is developed to influence the electrometer. Some electric disturbance is manifested by almost every individual, if it be carefully sought for. In men, it is most frequently positive; and irritable men, of sanguine temperament, have more free electricity than those of phlegmatic character; whilst the electricity of women is more frequently negative than that of men. Some individuals exhibit these phenomena much more frequently and powerfully than others. There are persons, for instance, who scarcely ever pull off articles of dress which have been worn next the skin without sparks and a crackling noise being produced, especially in dry weather; this may, however, be partly due to the friction of these materials on the surface, and with each other, as it has been proved to be greatly influenced by their nature. The most remarkable case of the generation of electricity in the human subject at present on record, is one that has been met with in America (*American Journal of Medical Science*, January 1838). The subject of it, a lady, was for many months in an electric state so different from that of the surrounding bodies, that whenever she was but slightly insulated by a carpet, or other feebly conducting medium, sparks passed between her person and any object which she approached. From the pain which accompanied the passage of the sparks, her condition was a source of much discomfort to her; when most favourably circumstanced, four sparks per minute would pass from her finger to the brass ball of the stove, at the distance of one and a half inch. The circumstances which appeared most favourable to the generation of electricity, were an atmosphere of about 80°, tranquillity of mind, and social enjoyment; while a low temperature and depressing emotions diminished it in a corresponding degree. The phenomenon was first noticed during the occurrence of an aurora borealis; and though its first appearance was sudden, its departure was gradual. Various experiments were made, with the view of ascertaining if the electricity was generated by the friction of the articles of dress; but no change in these seemed to modify its intensity. It was no doubt generated, or the electrical equilibrium was disturbed in an undue and very extraordinary degree, by the condition of the nervous system, probably influenced by some deranged condition of certain of the organic functions. It seems to have been proved that electrical manifestations are the invariable consequence of the action of the nerves in producing muscular action; and it is probable that this powerful agency of electricity exercises an important influence on the digestive processes, and perhaps especially in facilitating the decomposition of the food, and so far preparing it to enter into new combinations for the nutrition of the body. But however this may be, and however large, or little important, the influence of electricity may be in

carrying on the vital and organic processes of the system, there is no doubt that a certain amount of electrical matter is constantly being given off from the surface of the living body; that the amount of this varies according to the dryness or dampness, the coldness or warmth, of the atmosphere; and that the degree to which it is permitted to escape may be influenced by the nature of the clothes, and particularly according to the nature of the fabric which is worn next the skin; and that the escape of this electricity is so far attended with diminished power and energy of the general economy, and in the same degree to which such escape may be prevented, is the system maintained in a state of more vigorous vitality. The depressing influence of wet and cold weather may be largely referrèd to the effect of such an atmosphere in carrying off rapidly the free electricity of the system; and the colder and more damp the climate man lives in, the more important is it that he surround the body with such articles of clothing as will check, as far as may be, the escape of this extraordinary agent; and the greater the habitual depression and debility of the economy, the less the degree of its vital energy, the more important does this consideration become.

'Silk, as a remarkable non-conductor of electricity, deserves to be made use of more generally than it is in this country, as an article of underclothing. For this purpose, it should be woven entirely of what is called *bright* or *wrought* silk, in contradistinction to what is called *spun* or *spurious* silk; and the under-garment is to be manufactured in a similar way, and of a similar material, to stockings; but woven with much thicker thread into a very thick and heavy fabric.'

Furs and *down* are by far the warmest materials, but in Britain they can scarcely be considered as articles of general clothing. Soft, light, elastic, they constitute excellent adjuncts during the winter months, while their fine colours and markings add greatly to their appearance. When worn, as furs usually are, with the skin attached, they are rather impermeable to exhalations, and are not in this light to be considered as equal to the finer fabrics woven or knitted from wool. *Leather*, unless peculiarly prepared (as chamois), is by no means fit to be worn as an inner garment; in fact, the common application of this material is for boots and shoes, for which it is admirably suited by its strength and durability. Unless made somewhat easy, so as to allow room for a worsted sock or stocking and a certain amount of air, leathern boots form but a cold covering, at the same time that they are all but impermeable to any kind of exhalation. When well manufactured, leather should be soft and pliable; and when fashioned into shoes, these should be rather large and easy. There is, in general, no member of the body more sinned against—the chests of stay-wearing ladies scarcely excepted—than the foot; and the certain penalty is corns, callosities, and deformities, an unspeakable amount of pain, and in the long-run, a partial destruction of the powers and functions of one of the most essential of the bodily organs. The feet, with proper treatment, ought to be as free from disease and pain as the hands, their structure and adaptation to the wants and comforts of man being naturally perfect. 'Thirty-six bones and thirty-six joints,' says a writer on the foot, 'have been given by the Creator to form one of these members, and yet man cramps, cabins, and confines this beautiful arrangement of 144 bones and joints—together with muscles, elastic cartilage, lubricating oily fluid, veins, and arteries—into a pair of boots or shoes, which, instead of forming a protection, produces the most painful and permanent injuries.' These objections as to room cannot be urged with the same force against the numerous *elastic fabrics* now coming into use, as these, to a certain degree, expand and contract according to the requirements of the foot; but then there is this objection—all of them are impermeable to perspiration. The foot while heated perspires, the moisture is not allowed to exhale, and on resuming a state of rest, cold and damp is the result. This objection, indeed, is fatal to all the elastic *waterproof fabrics* now so much in vogue: the insensible perspiration must be absorbed or exhaled, and if not, discomfort and disease are the inevitable consequences. Numerous ingenious attempts have been made to remedy these defects, so as to retain the other valuable properties of elastic and waterproof clothing; but as yet we have seen none completely successful; and for our own parts, we would rather undergo a drenching which can be laid aside with the garment which sustains it, than sit for hours enveloped in offensive exhalations.

Amount of Clothing.

The amount of clothing should be regulated as much as possible in reference to the climate under which we live, the season of the year, the degree of exposure to which we are subjected, the exercise or fatigue we undergo, the food consumed, age, sex, and other constitutional peculiarities. Thus, other things being equal, a cold climate requires a heavier and thicker dress than a warm one: in winter we could not wear a light summer dress with impunity; a man undergoing healthful exercise in the open air needs less muffling up than a sedentary dweller within doors; the individual enjoying a full invigorating diet feels comfortable in garments under which an ill-fed man would shiver; and, generally speaking, the young and vigorous require less clothing than the aged and infirm. Regarding the first of these circumstances as axiomatic, let us consider the others in detail.

1. Although it is proper to adapt the warmth of our clothing to the season of the year, yet change in this respect must be made with caution. The animal constitution is no doubt endowed with considerable plasticity; but that plasticity must be operated upon by insensible gradations. 'Very light clothing during the summer months,' says an able writer on domestic economy, 'exposes the body to the effects of those sudden changes of weather which we experience in our climate. It is safer to wear the same clothing nearly all the year than to make frequent and sudden changes; exercise under too warm a dress occasions violent perspiration, the effects of which are often dangerous. It is remarkable that in some countries custom differs materially from ours respecting clothing. We dress in general somewhat warmer when we go out than when we sit indoors: the Turks, who seldom have fires in their apartments, keep themselves comfortable within doors by using warmer clothing than when they go out, considering the practice of moving about a source of heat, which it really is: the Chinese of rank, it is said, practise the same mode—putting on an additional garment in the house, which they throw off as the sun ascends to the meridian, and resuming it in the cold of the evening.' 2. As to exercise, there can be no doubt that it is a source of heat: respiration goes on more briskly, the carbon of our food and blood is more rapidly consumed, a greater degree of heat is experienced, and this continues so long as the body is in a healthful vigorous condition. To overload one's self with dress during exercise is but to irritate and fatigue; at the same time care is required on relapsing into a state of rest, that the exhausted frame be properly protected. During exhaustion every function goes on less briskly, little heat is supplied by respiration, and that little requires to be carefully retained. 3. The same remarks are applicable to the case of food. A well-fed man (see PHYSIOLOGY) has a source of heat within him; and if the doctrines of Liebig and others be correct, food may be said to supplement clothing, and clothing food. If we lose heat through lack of clothing, the food must supply it; and *vice versâ*. 4. The young and vigorous, other things being equal, require less clothing than the old and infirm. While the respiration and circulation of the system is vigorous, and the diet wholesome and full, every function is performed with

activity; heat is freely formed; and the exercise generally taken by the young greatly augments the supply. But the young and vigorous must not neglect the ordinary rules of clothing on this account—a neglect they are but too apt to perpetrate, and which, in the case of infancy, is too often perpetrated against them by ignorant nurses, and equally ignorant and foolish mammas. 'Are the little "Highlanders,"' asks Dr Erasmus Wilson, 'whom we meet during three out of the four quarters of the year under the guardianship of their nursery-maids, dawdling about the streets in our public walks or squares, properly protected from the cold? Are the fantastically attired children whom we see "taking an airing" in carriages in our parks, sufficiently and properly clad? If these questions can be truly answered in the affirmative, then, and then only, my remarks are needless. There can enter into the parent mind no more baneful idea than that of rendering children "hardy" by exposing them unnecessarily to cold, and by clothing them inefficiently. I have known instances wherein parents, acting on this principle, have failed entirely in rearing their offspring. Does nature treat her progeny thus? Does she not, first of all, insure the birth of her young only at a kindly season, and then provide them with downy coverings, warm nests, and assiduous protectors? And WE must imitate nature, if we would give to Britain a race capable and worthy of maintaining her independence and honour. The little denizens of a warm nursery must not be subjected, without a carefully assorted covering, to the piercing and relentless east or north-east wind; they must not be permitted to imbibe the seeds of that dreadful scourge of this climate—consumption—in their walks for exercise and health; they must be tended, as the future lords of the earth, with jealous care and judicious zeal. *One-sixth of the deaths of young children*, it must be remembered, *result from cold.*' 'The large mortality,' says another medical authority, 'among the children of the poor, is to be referred to an undue exposure of their feebly acting and sensitive surfaces to the influence of the cold.' It by no means follows, however, from what has been said, that the systems of the young are to be overheated, relaxed, and enfeebled by an excessive amount of clothing, an amount disproportioned to the requirements of health and growth.

As to special articles of dress, and the clothing of special parts of the body, there is often injudicious management, partly from mistaken physiological notions, and partly from caprice and fashion. Thus there is nothing more common than to dress heavily when we go out of doors, and put on some thin flimsy covering within doors; to clothe well during one portion of the day, and be in loose, open, undress during another; to wear strong boots or shoes when we take open-air exercise, and immediately thereafter to be sedentary and in slippers. Such sudden changes are contrary to all reason, and cannot fail to be prejudicial to sound health and comfort. The human body is not a piece of mechanism, which can be wound up and adjusted at pleasure; and far less is it to be tampered with in direct opposition to the natural laws under which it is constituted. What more preposterous than to dress heavily when under the warming influence of exercise, and to dress loosely and lightly when sedentary, and when all the functions of circulation and respiration are languid and slow! Another error, very common in this country, is the inordinate wrapping of the neck and shoulders with kerchiefs, shawls, and furs. To behold men and women, old and young, all be-muffled and be-boa'd, no matter what the day or what the occasion, a stranger would be apt to imagine the country labouring under one huge epidemic; and yet the truth might be some absurdity of fashion—some monkey imitation of A by B, C, D, and all the other letters of the alphabet. 'Unless when much or unusually exposed to the influence of cold,' says a high medical authority, 'the risk of local relaxation from this practice, and of an unadvisable degree of chill when such extra clothing is removed, deserve consideration, and may lead to greater evils than such extra wrapping is calculated to obviate. It is only justifiable under circumstances of extreme and long-continued exposure to cold, or in the instance of very delicate and susceptible systems.'

Another instance in which very irrational and often fatal errors are committed, is the due protection of the feet. 'Of all parts of the body,' says the same authority, 'there is not one the clothing of which ought to be so carefully attended to as the feet. The most dependent part of the system, this is the part in which the circulation of the blood may be the most readily checked; the part most exposed to cold and wet, or to direct contact with good conducting surfaces, it is the part of the system where such a check is most likely to take place. Coldness of the feet is a very common attendant on a disordered state of the stomach; and yet disordered stomach is not more apt to produce coldness of feet, than coldness of feet is apt to produce disorder of the stomach; and this remark does not apply only to cases of indigestion, but to many other disorders to which man is liable. Yet do we see the feet of the young and delicate clad in thin-soled shoes and as thin stockings; no matter whether the weather is dry or damp, or whether the temperature of the atmosphere is warm or cold. But this is not the whole of the evil. These same feet are frequently, at different times of the day, differently covered as to stoutness of the shoes and their soles, and very often likewise as to the thickness of the stockings. . . . . I am sufficieut of a Goth to wish to see thin-soled shoes altogether disused as articles of dress; and I would have them replaced by shoes having a moderate thickness of sole, with a thin layer of cork or felt placed within the shoe, over the sole, or next to the foot. Cork is a very bad conductor of heat, and is therefore to be preferred. Its extreme lightness, the remarkable thinness to which it may be cut, its usefulness as a non-conductor not being greatly impaired thereby, and the inappreciable effect it has on the appearance of the shoe, all seem to recommend its use for this purpose in the strongest manner.'

Among the special instances of error as to the amount of clothing, the writer just quoted places pre-eminently that of bed-clothes. In Britain, where a great variety of material is used—such as feathers, down, hair, woollen blankets, cotton counterpanes, and linen sheets—this subject is deserving of more attention than it generally receives; and all the more seeing that while in bed the skin usually throws off much more of its secretions than at other times. What is required is a mere sufficiency to keep the surface warm; everything beyond this is exhausting and detrimental. What is sought for in bed is rest, quietude, and a total avoidance of all excitement; and this most certainly cannot be obtained when half-smothered, heated, and irritated by an undue amount of warm clothing. 'A free and sufficient use of exercise, and particularly walking-exercise; a regular exposure to the open air; a daily change of air, as far as may be practicable—walking as far away from home as strength, and time, and weather allow, instead of confining the exercise to a circle near the house; and a regulated diet, are the great means, next to sufficiently frequent ablutions, of keeping the vessels of the skin in a state of efficient activity, and preserving or restoring the natural temperature of the surface. And this point having been gained, very few and light bed-clothes are all that will be required.

COSTUME.

Dress may be said to consist of three generic forms—the simple attire of savage life, in which a skin, blanket, or some other loose covering, is nearly all that is employed; the flowing and elegant dress of the East;

and the precise and more closely fitting clothing of modern European nations. Of the first mentioned, little need be said. In the absence of manufactured articles, savage tribes in all countries are, and have been, in the habit of attiring themselves in such rude materials as nature has placed within their reach. The Indian of North America clothes himself in skins on which the fur is left, or with a blanket procured from the wandering trader. His legs and feet he dresses in moccasons made from a species of leather, and in full dress he fancifully paints his skin with pigments. In some of the islands of the Pacific—as also till lately in New Zealand—the inhabitants *tattoo* the surface of the body, by puncturing it with an instrument, and inserting coloured juices in the wounds. Such, likewise, was the barbarous practice and fashion of the original inhabitants of the British Islands.

North American Indian.

Throughout Asia, in North Africa, and in Turkey, the dress is generally of a loose and flowing form, that of the common people in China being least so. The *turban* is almost universal. It is a male head-dress, composed of muslin swathed in folds, for the most part round a cap; and by presenting a mass of light material to the sun, it is considered to be a suitable covering for the head in Eastern climes. The forms of this head-dress, however, differ considerably, some being more tasteful than others. The first represented in the accompanying figure is the round turban common in Africa; the second, an elegant modern Egyptian form.

A crowd in Constantinople, previous to the late modifications of costume, was, says a traveller, a picturesque group: 'there was the graceful Effendi Turk with snow-white turban, jetty beard, sparkling and full eyes, long flowing caftan, scarlet trousers, yellow boots, rich Cashmere shawl round the waist, in which shone the gilded dagger; next was the gay but cunning-looking Greek, with short chin, black turban, enormous but short trousers, bare legs, and black shoes; then the grave Armenian, with his calpac of black felt balloon-like upon his head, his long Turkish robe, silver ink-horn in his girdle, and his feet in the crimson slipper or boot; next was the Jew, with his blue turban and slippers; and with these were seen the high taper calpac of the Tatar, the melon-shaped head-piece of the Nizam Djedid, the gray felt conical cap of the imam and dervish, and occasionally the ungraceful hat of the Frank, with the be-buttoned and mean-looking costume of Western Europe.'

The dress of the modern Greeks is a mixture of Eastern and European costume, with little to mark the classical origin of the people. The chief article of attire of the poorer Greeks is a *capote*, or large woollen garment, with a hood, shaggy with short threads of yarn; it is heavy when dry, but nearly insupportable when wet; it is as serviceable for home and bed to the wandering Greek as the *bunda* is to the Hungarian shepherd, and it is a perfect defence against cold and dew. All but the poor classes of Greeks, however, dress showily, and even a servant will expend every farthing of his wages in fine clothes. Thus a physician's janizary may be seen in a rich robe of scarlet, his vest of blue velvet trimmed with gold-lace, and in his silk girdle a brace of pistols embossed with silver; turban, short petticoats, and trousers of purest white, and gaiters or 'leggings' of scarlet velvet, embroidered with gold; altogether, a costume that might suit a prince. The general dress consists of a short embroidered jacket, without collar, and with sleeves open from the elbow; an embroidered vest, a cotton shirt, a tunic of several folds, secured by a sash or shawl about the waist, and reaching to the knee; loose breeches or trousers, short socks, and slippers between sandals and shoes. In one corner of the sash, the common people carry their money, which the rich put into purses, and carry, with their handkerchiefs, watches, and snuff-boxes, in their bosoms. The head-dress is various; as the turban, *à la Turque;* the fur-cap, like a muff; the fez or tasselled cloth cap, worn on one side; the plain caps of the peasantry; and skull-caps of velvet or gold, embroidered and tasselled. The young Greeks are the handsomest race in Europe; their long hair falls over their shoulders from under the cap; their embroidered jackets, vests, and buskins, their arms mounted with silver, and even jewels, and their white kilts, compose, on the whole, one of the most graceful and becoming costumes in the world.

The Greek.

The costume of the Greek female more closely resembles that of the Turks. She wears loose trousers of fine calico, embroidered with flowers, a closely fitting vest, a jewelled zone about the waist, and a long-sleeved gown, flowing off loosely behind, or a veil covering the body; and sometimes a rich pelisse trimmed with fur. Jewellery is worn to excess; and bracelets of gems, or strings of gold coins round the arm and neck, across the forehead, and in the hair, which the younger girls let fall down their backs and over their brows and cheeks. Little caps, similar to those of the men, are also worn by the females, studded with coins, but worn on one side of the crown, the girls wearing in them flowers, and the matrons heron-plumes or jewels. The young women often dye their hair auburn, and the old ladies red, with which colour the nails are also tinged. The females walk abroad in a robe of red or blue cloth, and an ample muslin veil.

The dress of modern Europe, and, we may add, that of civilised America, differs little in essentials. With few exceptions, it is well fitted for an active, hard-working, city-dwelling people; it has little cumbrous or unnecessary about it, and if not always so graceful or picturesque as could be wished, it is free at least from the reproach of 'barbaric pomp and ornament.' Climate, business avocations, and conventional usages, require it to be somewhat precise; but this precision can never become ridiculous unless through some temporary freak of what the gay world denominates *fashion*. The usual notions concerning flowing or classical costume are more traditionary than rational; for if there be really anything in 'the human form divine,' the less that any costume clogs, and cumbers, and conceals it—consistently with comfort and decorum—the more becoming must it of necessity be. With this much for the too often reviled costume of modern Europe, and without entering into particulars

as to the styles it assumes in different countries, we shall now devote the remaining pages to the history and development of

BRITISH COSTUME.

Partly from a wider acquaintance with other countries, partly from the introduction of new pursuits and avocations, and partly from caprice and fashion, the costume of our country has undergone many changes in the course of ages. Among the Southern Britons, at the time when Julius Cæsar landed in the country (55 B.C.), the arts connected with clothing had made some advance; but in the more northern parts, the practice of living half-naked, with painted and tattooed bodies, was common, and, notwithstanding the severity of climate, remained till a much later period. Such fanciful decorations are supposed to have given name to the nation of *Picts* (from the Latin word *picti*, painted); but on better authority, the appellation has been referred to a different origin.

Pict.

The usual Roman dress, in the latter period of the Empire, consisted of a tunic, or loose upper garment, with a dress for the lower limbs, called *braccæ;* hence the modern term *breeches*. Over all was occasionally worn by the higher classes the *toga*, or mantle. It is believed that these Roman costumes were generally copied by the greater number of British, at least among the more opulent classes. In the dress of the women, however, there was but little change. They appear in two tunics, the one reaching to the ankles, the other having short sleeves, and reaching about half-way down the thigh: in other words, they resemble a round gown, or bed-gown and petticoat, though the latter, distinct from a body and sleeves, is not considered to be ancient. This tunic was called in British *gwn;* hence our word *gown*, of which we still see specimens of short dimensions worn by women of the humbler classes in England, Scotland, and Wales.

Anglo-Saxon and Danish Periods.

The Anglo-Saxon and Danish periods of English history are marked by new peculiarities in costume. Soon after the departure of the Romans and the arrival of the Saxons in 449, fashions of apparel were introduced from Northern Germany, which were copied by the Romanised British, and continued with no material change for several centuries.

The most important improvement in the ordinary dress of the people was the introduction of the *shirt*, a linen garment worn next the skin, for which we are indebted to the Saxon invaders. The common dress of the eighth century consisted, as we find, of linen shirts; tunics, or a kind of surcoat; cloaks fastened on the breast or shoulders with brooches; short drawers met by hose, over which were worn bands of cloth, linen, or leather, in diagonal crossings. Leathern sandals were worn by the early Anglo-Saxons; but afterwards the shoe became common: it was very simple, and well contrived for comfort, being opened down the instep, and there, by a thong passed through holes on each side of the slit, drawn tight round the feet like a purse. A felt or woollen cap, called *hæt* (hence our modern word hat), was worn by the higher class of Anglo-Saxons; but it is generally believed that the serfs or lower orders were without any other covering for the head than what nature had given them.

Although Sir Walter Scott, with the natural modesty of genius, disclaims pretension to complete accuracy in the costume of the characters in his historical romances, the following portrait of Gurth, the Saxon swineherd, in *Ivanhoe*, is nearly correct: 'His garment was of the simplest form imaginable, being a close jacket with sleeves, composed of the tanned skin of some animal, on which the hair had been originally left, but which had been worn off in so many places that it would have been difficult to distinguish from the patches that remained to what creature the fur had belonged. This primeval vestment reached from the throat to the knee, and served at once all the purposes of body-clothing. There was no wider opening at the collar than was necessary to admit the passage of the head, from which it may be inferred that it was put on by slipping it over the head and shoulders, in the manner of a modern shirt or ancient hauberk. Sandals, bound with thongs made of boar's hide, protected the feet; and a sort of roll of thin leather was bound artificially round the legs, and, ascending above the calf, left the knees bare, like those of a Scotch Highlander. To make the jacket sit more closely to the body, it was gathered at the middle by a broad leathern belt, secured by a brass buckle, to one side of which was attached a sort of scrip, and to the other a ram's horn, accoutered with a mouthpiece for the purpose of blowing. In the same belt was stuck one of those long, broad, sharp-pointed, and two-edged knives which were fabricated in the neighbourhood, and bore even at this early period the name of a Sheffield whittle. The man had no covering upon his head, which was only defended by his own thick hair matted and twisted together. One part of his dress only remains, but it is too remarkable to be suppressed: it was a brass ring resembling a dog's collar, but without any opening, and soldered fast round his neck; so loose as to form no impediment to his breathing, yet so tight as to be incapable of being removed, excepting by the use of the file. On this singular gorget was engraved, in Saxon characters—"Gurth, the son of Beowulf, is the born thrall of Cedric of Rotherwood."'

Anglo-Saxon Serf.

The Anglo-Saxon females wore under-tunics, with sleeves; another inner garment—the linen kirtle; and over these the long full gown, with loose sleeves. The head-dress was a hood or veil, which, falling down before, was wrapped round the neck and breast; and this was the only head-covering of the women when abroad. The hair was carefully dressed, and golden head-bands, half-circles, neck-bands, and bracelets were worn; with ear-rings, necklaces, crosses, and jewelled ornaments too numerous to describe. The hose and shoes resembled those worn by the men. The long sleeves of the gown or the mantle, drawn over the hands, served as gloves, which were not worn before the eleventh century. All classes used on their cheeks a red cosmetic, so that the art of painting the face is not the creature of refinement. The general colours of the dresses were red, blue, and green, sometimes embroidered in patterns; and gold tissue and cloth of gold were worn by princesses and nuns; and the latter embroidered robes, sandals, tunics, vests, cloaks, and veils of enormous cost—for pearls and precious jewels were interwrought with the materials, and sometimes three years were spent in working one garment; and their dresses were often lined

with sable, beaver, and fox furs, or the skins of lambs or cats.

In the article of dress, the Danish intruders into Britain were, after a time, equally profuse. The Anglo-Danish kings appear principally to have worn a red habit, embroidered with gold, and a purple robe; and their mantles were richly embroidered with gold and pearls. Upon a manuscript of the reign of Canute, he is, however, represented in a Saxon dress, the mantle being richly ornamented with cords or ribbons, and tassels; and he wears shoes and stockings with embroidered tops. His body, when discovered in Winchester Cathedral in the year 1766, was decorated with gold and silver bands, and a richly jewelled ring; bracelets were worn by all persons of rank, and invariably buried with them. Canute's queen wore the tunic, mantle, and long veil. The materials of the Danish dresses were cloths, silks, or velvets, procured either from Spain or the Mediterranean, by plundering the Moors.

From the Danish invasion to the Norman Conquest there were few changes in costume, if we except the imitation of Norman-French fashions in the reign of the Confessor, by shortening the tunics, clipping the hair, and shaving the beard, but leaving the upper-lip unshorn. Tattooing after the Pictish fashion was practised even to this time, although it had been forbidden by a law passed in the eighth century.

Eleventh till Fourteenth Century.

The Norman Conquest introduced a greater degree of taste and splendour into British costume; but the dress of the common order of people remained long of a comparatively rude fashion, partly from the effect of caste and sumptuary laws, which prevented any decided change. As time advanced, the materials of dress improved, but the fashioning was little different, and, till this day, we have a sample of the Anglo-Saxon tunic in the *smock-frock*, a species of overall linen shirt, very generally worn by the peasantry of England. The *blouse*, a coarse linen shirt of blue instead of white, which is now universally worn by workmen in France, Switzerland, the Low Countries, and part of Germany, had an equally early origin.

In the reign of Rufus many costly changes were made in dress: the tunics were lengthened, and the under garments even trailed upon the ground. The sleeves were also drawn over the whole hand, although gloves were worn, at least by the higher classes. The cloth mantles were lined with rich furs; and one lined with black sables and white spots cost £100. Extravagantly peaked-toed boots and shoes were worn; and a court coxcomb, who caused the points of his shoes to curl like a ram's horn, received the name of *De Cornibus*, or with the horns. The hair, which had been shorn from the back of the head as well as the face by the Norman-French, was now again worn long; and the courtiers in Stephen's reign even wore artificial hair, so that wigs may date from the twelfth century. The long beard also reappeared in the reign of Henry I. (1100–1135).

About this period, *gloves* highly ornamented appear to have been used by kings and the higher church dignitaries. Gloves, or a clothing of leather for the hands, had not been unknown in early ages; by the Greeks and Romans they were employed as a protection in certain kinds of rough labour. Now they were employed as part of a mailed dress, and also on ceremonial occasions. From the monumental effigy of Richard I., it is seen that he wore gloves ornamented with jewels on the back of the hand. Throwing down a glove became a challenge of defiance to single combat, according to the etiquette of these partially barbarous ages. From being worn only by kings, archbishops, courtiers, and knights, gloves made of various materials gradually became a portion of ordinary dress.

In the course of the thirteenth century, the sumptuousness of apparel increased: rich silks woven with gold, embroidered and fringed, and French velvets, were much used; and a rich stuff manufactured in the Cyclades was made into a dalmatica or super-tunic, called Cyclas, which was worn by both sexes. The furs of ermines, martens, squirrels, the vair, and the minevair or minever, were added to the list of furs for winter garments.

The general male dress consisted of the cyclas just mentioned, and the tunic; but the principal novelty is the super-totus, or overall, worn like the mantle or cloak, and consisting of a kind of large-sleeved shirt, with a capuchon. Long-toed shoes and boots were resumed, with embroidery and colours.

The female costume differed in fashion and name, rather than in form, from that of the twelfth century. The veils were of gold tissue or superbly embroidered silk, and over them was worn a diadem, circlet, or garland, or a caplike coronet, by persons of rank, and sometimes a round hat. The head-dresses were very numerous: the wimple covered the head and shoulders, and was fastened under the chin; and the hair was worn in a net or caul of gold-thread, which continued in fashion for the next two centuries. A very ugly kind of wimple, called the gorget, appeared in the thirteenth century; it was a neck-covering, poked up by pins above the ears. The long robe was also worn trailing on the ground; the cloth stockings were embroidered with gold; and trinkets of gold, as buckles, rings, earrings, and chaplets, and jewels, were much worn. In this century, too, we first meet with the surcol, which Strutt calls a corset, bodice, or stays, worn over the rest of the dress, which enlarged in the skirt, and spread into a train: it was made high in the neck, and had long tight sleeves.

The dress of the working-classes may be supposed to have been improved about this period by the introduction of the worsted manufacture: it is stated to have been brought to the country by a colony of Flemings, who in the reign of Henry II. settled at *Worsted*, a village in Norfolk; hence the name of the fabric.

Fourteenth and Fifteenth Centuries.

We now come to the fourteenth century, in which Edward III. and his queen Philippa led the fashion in apparel. As seen from the effigy on his tomb, the costume of Edward is characterised by its dignified simplicity. The dalmatica is low in the neck, falls in straight folds to the feet, and is open in front nearly half its height, being embroidered at the edges of the aperture; the sleeves of the under-tunic have at each wrist a row of buttons, a fashion of the reign of Edward III.; the mantle, embroidered at the edges, is worn over the shoulders, and confined by a jewelled band across the breast; the shoes or buskins are also embroidered, and the hair and beard are patriarchal; the crown has been removed or lost. The effigy of Queen Philippa, also at Westminster, is equally distinguished by its simplicity; the skirt is long and full, the bodice closely fitting, the waist-belt jewelled, and the mantle ornamented on the shoulders, and confined by a diagonal band across the breast; and upon the head is a low crown, jewelled, and from it depends a kind of draped ornament half-way down the cheek. The costume of the nobles in this reign was, however, far less simple than that of the sovereign. In place of the long robe and tunic was worn a close-fitting body-garment (jupon) superbly embroidered, reaching to the middle of the thigh, and confined across the hips by a splendid belt; from the sleeves of this garment hung long slips of cloth, called *tirippes* (tippets), and over the whole was occasionally worn a long mantle, fastened by buttons upon the right shoulder. This dress was, however, the extreme of foppery. The caps were of various shapes, and among them we find the knight's *chapeau*, nearly in the form now used in heraldry. Beaver hats were also worn; but the greatest novelty was a single feather in

the front of the cap. The golden chaplets, by the addition of leaves, now assumed the form of coronets. The gay tournaments of this period led to the introduction of many costly foreign fashions; so that, in 1363, expensive dress, beyond the income or rank of the wearer, was forbidden by law; furs of ermine and pearl ornaments (except for head-dress) were forbidden to all but the royal family and the wealthiest nobles; cloths of gold and silver were permitted only to the next in fortune; and persons of small income were forbidden to wear silks, embroidery, or trinkets. But the ladies dressed still more sumptuously, as in the engraving, where the gown fits close in the bodice, and the train is so long in the front as to be held up, and thus display the embroidered under-dress; the sleeveless jacket worn over the gown is also embroidered and trimmed with fur; the hair is worn long, and the cap is low, and resembles a coronet. Tippets from short sleeves, and the jupon, were also worn by ladies as well as by gentlemen; and both sexes wore daggers stuck through pouches in their rich girdles. In this reign *mourning habits* appear to have been first worn, the colours being black and brown.

Lady of Fourteenth Century.

The reign of Richard II. must have been the high carnival of coxcombry. The sovereign himself, according to Holinshed, had a coat or robe which cost 30,000 merks. Party-coloured dresses were universally worn; and even the hose were of two colours, so as to render the term a *pair* inapplicable: the colours of the king and his court were white and red. Men and women alike wore hoods set with jewels; and their tippets were jagged, and reached to the heels; and the long-peaked shoes, called *crackowes* (from Cracow, in Poland), were fastened to the knees with gold and silver chains. The preceding engraving shews a gentleman of this period, with shoes and hose all in one, the mantle cut into the shape of leaves at the edges, a belt and pouch, and a fantastically turbaned head-covering. Chaucer has left us the costume of several ranks at this period: his squire wears a short gown, 'with sleeves long and wide;' his yeoman, 'a cote and hoode of grene;' his merchant, many colours, with a forked beard, and a 'Flaundrish beaver hat,' and clasped boots; the reeve or steward, a long surcoat and rusty sword, his beard and head shaven and shorn; the miller wore a white coat and blue hood, a sword and buckler, and red-cloth holiday-hose; and the hats, caps, and bonnets of all classes were very fantastical. Knives, ornamented with silver, and purses, were worn by most classes in their girdles; and shoulder-belts, with bells, were a mark of rank. Liveries are also now mentioned as worn by substantial artisans, as well as by menial servants; but the ploughman appears only in a tabard or sleeveless coat, and the mechanic in a tunic. The hair was worn long and curled, and the beard forked.

Gentleman of Fourteenth Century.

In the female costume of this reign the fantastic party-coloured dresses were retained, with the embroidered jupons and kirtles, hip-kirtles, and long tippets from the elbow; and the surcol, or external corset, faced with fur, and terminating in a train sometimes so long as to be carried over the arm, or shorter, opened up the side, and bordered with ermine. The head-dress continued as in the preceding reign. The attire of the carpenter's wife in the *Canterbury Tales*, with a silk girdle and head-fillet and brooch, indicates the condition of this class of females.

The costume of the fifteenth century was equally gay and foppish, but perhaps more neat in form. The annexed engraving represents a gentleman of the reign of Henry V.: he is dressed in a short tunic, buttoned in front, with girdle, large loose sleeves, tight hose forming pantaloons, and stockings in a single piece, peaked shoes, and head-cloth or cap. About this period, silks and velvets of divers colours came into use among the higher classes, by whom gold chains were generally worn. The dress of ladies was of the richest kind. Gowns were embroidered and bordered with furs or velvet; and the bodice, laced in front over a stomacher, now first appeared. But the greatest eccentricity was the lofty steeple head-dress, shewn in the annexed portrait; this consisted of a roll of linen, covered with fine lawn, which hung to the ground, or was mostly tucked under the arm.

Gentleman of Fifteenth Century.

Richard III. (1483 - 1485), according to his wardrober's books, was a right royal fop; for we find him wearing a blue cloth-of-gold doublet and stomacher, 'wroght with netts and pyne-apples,' and crimson and purple-velvet robes, embroidered and furred, and crimson satin hose, and tissue cloth-of-gold shoes, at his coronation. The nobles in this reign had their hose tied by points to the doublet, which was sometimes worn open, but laced like a bodice; and over it was worn a long or short gown, the former hanging loose, and the latter plaited before and behind, and girded about the waist; and both gown and doublet were slashed. The general head-dress was a closely fitting cap or *bonet* (bonnet), with a single feather in it; and scarlet hats and hoods were worn. The boots had very long-pointed toes, and reached to the middle of the thigh.

Lady of Fifteenth Century.

Hitherto the authorities for costume have been illuminated manuscripts, tapestry, and monumental effigies, in which there is often perplexing indistinctness. Now, painting comes to our aid; and the portraits by Holbein are the best illustrations of the costume of the two succeeding reigns. The male costume of the wealthier classes in the reign of Henry VII. consisted of a fine shirt of long lawn, embroidered with silk round the collar and wristbands. The sleeves of the doublet were slashed at the elbow, as in the reign of Edward IV.; or they were in two or more pieces, fastened at the shoulders and elbows with laces or points, through which the shirt protruded. The doublet was laced over a stomacher and petticoat, the male costume thus resembling that of the females in name as well as form. The outer garment was a long coat or gown, with loose hanging sleeves, and a broad turn-over collar of velvet or fur. The long hose were

differently coloured in the upper and lower portions, and in the former slashed or puffed; the shoes were absurdly long and broad-toed, and high boots were worn for riding. In the head-coverings there was great variety. The hoods were abandoned to official habits, and instead were worn broad felt-hats or caps, and bonnets of velvet or fur profusely decked with ostrich feathers; or the large plumed cap was slung at the back, and a smaller cap of velvet or gold net worn on the head. The knave of our playing-cards has a cap peculiar to this period.

In these distracted times, party-colours were worn. Thus, the family colours of the House of Lancaster were white and red; those of York, purple and blue; and those of Tudor, white and green. Buttons also bore partisan figures or emblems.

The female costume of the reign of Henry VII. is distinguished by the square cut of the bodice in the neck, and embroidered and jewelled stomachers, belts, and girdles hanging in front nearly to the feet; the sleeves were large and full, and when confined at the wrist resembled 'the bishops' sleeves' imitated in England, from the French, a few years since. These sleeves were slashed, divided, and joined like those of the men. The head-dresses were close caps and cauls, from beneath which the hair hung down to the waist; and several kinds of capuchons were worn. In the dress of the humbler classes we find mentioned a 'furred flocket and gray russet rocket,' 'kirtle bristow red,' 'blanket hose,' 'Lincoln green,' &c.

At the close of this century the mourning habits had become so sumptuous as to be limited by law; the principal article being a barb or veil, used at funerals, which was tied on above the chin by duchesses and countesses, and lower by all other ranks.

Throughout the above period the principal material of the clothing of the middle classes must have been abundant; for, in the reign of Edward III., our woollen manufacture almost rivalled that of the Flemings, and our exports to the continent were very large; there appears, however, to have been little or no linen made at this period in England.

Sixteenth Century.

In the sixteenth century the upper part of the long hose began to be worn loose, or slashed with pieces of different colours let in, and the arms and shoulders of the doublet or jacket were fashioned in a similar style. Boots were also worn loose on the leg, with the upper part falling down; hence the origin of the *buskin*. Ruffs or ruffles, collars, and velvet bonnets with feathers, came likewise into use, as may be seen from the paintings of Henry VIII. Hall, the chronicler, describes several of Henry's superb dresses, and among them a *frocke*, or coat of velvet, embroidered all over with gold of damask, the sleeves and breast cut and lined with cloth of gold, and tied together 'with great buttons of diamonds, rubies, and orient pearls.' The cloaks and mantles were of corresponding magnificence. The shirts were pinched or plaited, and embroidered with gold, silver, or silk. The term *hose* continued to be applied to the entire vestment, from the waist to the feet, throughout this century: the material is more distinctly stated, for Henry wore knit silk as well as cloth hose; the precise period of the separation of the hose into breeches and stockings, is not so clear as the derivation of the latter term from the '*stockying* of hose;' 'that is, adding the lower part that covered the legs and feet to that which was fastened by points to the doublet,' and was called the *stocks*. The shoes and buskins were of the German fashion, very broad at the toes, and of velvet and satin, slashed and puffed. The hats, caps, and bonnets were of almost endless forms and colours.

Henry passed sumptuary laws, directing that cloth of gold and tissue should be used only for dukes and marquises, and that purple should be kept for the royal family. Earls might use embroidery, and commoners of distinction silks and velvets; and it was even thought necessary to restrict the commonalty and serving-men to cloth of a certain price, and lambs' fur, and to forbid them wearing any ornaments, or even buttons, save the badge of their lord or master. The king, likewise, forbade his courtiers wearing long hair, according to the general fashion, and made them poll their heads, which led to the introduction of the perûke, afterwards written *periwig*, and more shortly *wig*. The masques, or plays in masquerade, in Henry's reign, were very splendid; and in the ladies' dresses worn at one of them are mentioned 'demy sleeves, naked down from the elbows,' which M. Planché considers to have been the first appearance of bare arms since the time of the ancient Britons. Gloves were not unknown, for Henry left a pair to one of the executors of his will. They were sometimes finely perfumed, and brought from Spain and Italy as presents. In this and the preceding reign the head-dresses assumed a different character, having long lappets or ear-pieces hanging down below the shoulders, and when made of velvet studded with pearls, jewels, and gold, they were truly superb. Three-cornered caps of minever were also worn throughout the reign; and the close-fitting cap reaching to the ears, and known as 'Mary Queen of Scots' cap,' was first worn about this period. The ladies' hunting-dress differed but little from the riding-habit of the present day; across it was usually slung, from the right shoulder to the left side, a horn resembling a bugle.

In this reign, *pins* were first brought from France, and used by Catharine Howard, before which time the different parts of the dress were kept together by ribbons and loopholes, laces with points and tags, clasps, hooks-and-eyes, and skewers of brass, silver, and gold; but the poorer classes used the natural thorn for the above purpose.

The dress of the middle ranks in this reign may be seen in prints of the time; plain russet coats, and white kersey sloppes, or breeches, with stockings of the same piece, were the ordinary suit; and the London apprentices wore blue cloaks in summer, and gowns of the same colour in winter, as badges of servitude; for this appears to have been the age of domestic distinctions — the relics of the feudalism of the middle ages. The women wore sheep, russet, or long woollen gowns, worsted kirtles (hereafter called *petticoats*), and white caps and aprons; and milkwhite underlinen came into general wear. The engraving shews a man and woman in the ordinary dress of this period.

Man and Woman of the Sixteenth Century.

The principal novelty of the reigns of Edward VI. and Mary was the flat round bonnet or cap, of plain velvet or cloth, worn on one side of the head, and decorated with a jewel and single ostrich feather. The bonnet itself is preserved in the caps worn at the present day by the boys of Christ's Hospital; and their blue coat and yellow stockings are such as were worn by the London apprentices at the date of the foundation of the hospital by the youthful Edward. The gown of the wealthier classes was furred with sables in front and round the broad sleeves. Philip, on his marriage with Mary, brought into England a richer style of dress for the men, particularly the close ruff; the doublet, which fitted exactly under the chin, and the short Spanish cloak—all of which remained for a considerable time in fashion. The preposterously large stocks, or trunk-hose,

continued to be worn, but the broad-toed shoes were discarded. The armour continued nearly the same as in the preceding reign. To female costume the chief addition was the *fardingale*, an immense hooped petticoat, introduced from Spain under Queen Mary. The entire dress was worn very close, so as to conceal the person as much as possible.

Queen Elizabeth's fondness for dress is well known; she is stated to have left three thousand different habits in her wardrobe. This great number is explained by the royal affectation of wearing by turns the costume of all the nations of Europe, which may be traced to the use of foreign materials made up by foreigners. Bohun, in his character of Elizabeth, tells us that 'when she appeared in public she was richly adorned with the most valuable clothes, set off again with much gold and jewels of inestimable value; and on such occasions she even wore high shoes, that she might seem taller than indeed she was. The first day of the parliament she would appear in a robe embroidered with pearls, and upon her head she had a small crown. She was dressed in white silk, bordered with pearls of the size of beans, and over it a mantle of black silk, shot with silver threads. Her train was very long. Instead of a chain, she had an oblong collar of gold and jewels.'

But the glory of the Elizabethan era of female costume, as well as its most remarkable characteristic in the sixteenth century, was the *ruff* of plaited linen or cambric, which now became superb, and rose from the front of the shoulders behind the head nearly to its full height; from the bosom descended a huge stomacher, on each side of which projected the immense fardingale. In this characteristic costume Elizabeth went to St Paul's Cathedral to return thanks for the defeat of the Spanish Armada; though, besides the magnificent ruff, the queen wore a mantle with a large wing-like collar, her hair intertwined with pearls, large pendent jewels on the neck, and a superb lattice-work of pearls over the entire dress.

The ruff must, however, be further noticed: no sooner had its material been changed from Holland to lawn or cambric, than a difficulty arose as to starching or stiffening it, instead of the clumsy mode of supporting it by poking-sticks of ivory, wood, or gilt metal. At length the art of starching was brought from Flanders, and taught in London for a fee of four or five pounds. The fashion next lay in the colour of the starch, of which there were five varieties.

Stockings, which we find mentioned as foreign rarities in the wardrobe accounts of Henry VIII. and Edward VI., became common of home manufacture in the reign of Elizabeth. In the third year a pair of black knit silk stockings, made in England, was presented to her majesty, who was so pleased with the article, that she would never after wear cloth hose. This resolution has been attributed to Elizabeth's desire to encourage English manufactures by her own example, and may be taken as some set-off to her extreme fondness for foreign materials and fashions of dress. Soon after this, a city apprentice, having borrowed a pair of knit worsted stockings brought from Mantua, made a pair like them, which he presented to the Earl of Pembroke; and these are the first worsted stockings known to have been knit in England. Mary, queen of Scots, at her execution, wore stockings of blue worsted, clocked and topped with silver, and under them another pair of white; and the stockings of this time generally consisted of silk, jarnsey, worsted, crewel, fine yarn, thread, or cloth, of all colours, and with clocks, open seams, &c. The invention of the stocking-frame by Lee at Calverton, near Nottingham, in 1599, must have brought stockings into general use: he or his brother is said to have worked for Queen Elizabeth: but he was driven by the jealousy of the other stocking-manufacturers into France, where he died of a broken heart—an end by no means uncommon in the lives of inventors.

The garters of this age were very costly, sometimes of gold or silver, and £4 or £5 a pair; they are presumed to have been worn by ladies since the time of Edward II., but they must not be confounded with the leg-bandages of an earlier date. The ladies wore 'cocked shoes, prismets, pantoffles, or slippers,' which raised them two inches or more from the ground: these were made of black, white, green, or yellow velvet, or Spanish and English leather, embroidered with gold, silver, or silk, and shaped after the right and left foot, like the Anglo-Saxon sandal. The Elizabethan head-dresses were French hoods, hats, caps, kerchiefs, cauls of net-wire, and lattice caps—the latter, as well as an ermine bonnet, being forbidden by law to all but 'gentlewomen born, having arms.' In Elizabeth's jewel-box is a long list of wigs, or rather head-dresses, among which are cauls of hair set with seed-pearl and gold buttons. The hair was curled, frizzled, and crisped, and under-propped with pins and wires into the most fantastic forms. The finger-rings, earrings, bracelets, and other jewellery, were very splendid: velvet masks and pocket looking-glasses were carried by fashionables, with fans of ostrich feathers set in gold, silver, or ivory handles—the latter introduced from Italy, and used by both sexes.

The male costume in Elizabeth's reign was the large trunk hose, long-waisted doublet, short cloak, hat, band, and feather, shoes with roses, and the large ruff; but the great breeches, 'stuffed with hair like woolsacks,' after the separation of the hose into this garment and stockings, appear to have been worn throughout the reign: they were made of silk, velvet, satin, and damask. The doublets were still more costly, and quilted and stuffed, 'slashed, jagged, pinched, and laced;' and over these were worn coats and jerkins in as many varieties as there are days in the year. The cloaks were of the Spanish, French, and Dutch cuts, of cloth, silk, velvet, and taffeta of all colours, trimmed with gold, silver, and silk lace and glass bugles, inside and outside equally superb. The stockings, shoes, slippers, and ruffs resembled those of the ladies.

Hats now began to supersede the bonnets of a former era. Those of beaver were exceedingly expensive, and they were for the most part made of felted wool, dyed. The most remarkable thing about these hats was their numerous shapes: some were steeple-crowned; others were flat and broad, like the battlements of a house; and others with round crowns, and bands of all colours, and ornamented with huge feathers and brooches, clasps, and jewels of great value.

In taking leave of the British costume of the sixteenth century, we may observe that its splendour was almost entirely borrowed from France, 'that country which has since given laws in dress to nearly all Europe.'

Seventeenth Century.

Under James I. the male costume was somewhat more decidedly Spanish, as respects the slashing and ornamenting of the doublet and breeches. Late in the reign, however, the jackets or doublets were shortened, and the breeches reduced in size, and fastened in large bows at the knees; the well-stockinged leg was admired, and the hat worn low in the crown, and with broad brim, as seen in portraits of the date 1619. Beards and whiskers had become almost universal in the reign of Elizabeth; but in that of James, the former was sometimes worn trimmed to a point, hanging down at the division of the ruff.

In the female costume there was little change. The huge fardingale continued to be worn by the nobility; a strong passion for foreign lace was introduced; pearls were the favourite jewels; and the ruff maintained its sway, so as to be anathematised from the pulpit; and the fancies of female costume were glanced at in a sermon preached before the king at Whitehall in 1607–8, as 'her French, her Spanish, and her foolish fashions;

her plumes, her fannes, and a silken vizard, with a ruff like a sail, yea, a ruff like a *rainbow*, with a feather in her cap like a flag in her top, to tell which way the wind will blow.'

The dress worn in the reign of Charles I. is unrivalled for picturesqueness and elegant taste. At this we shall not be surprised, if we recollect that it was copied from the habit of Spain, the most becoming of all European costumes. Early in this reign, however, the motley fashion of the time of James I. prevailed; and the Savoy neck-chain, the ruff and cuffs of Flanders, the Naples hat with the Roman hat-band and Florentine agate, the Milan sword, and the cloak of Geneva set with Brabant buttons, gloves from Madrid, &c., were the characteristics of the beau of 1629. The ruff had almost universally given place to the falling band; and collars of rich point-lace, large and hanging down on the shoulders, held by a cord and tassel at the neck, and now called *Vandyke*, from its being the most striking part of the dress in which Vandyke at that time painted portraits.

The principal habits were vests and cloaks of velvet, or silk damask, short trousered breeches terminating in stuffed rolls, and fringes and points, and very rich boots, with large projecting lace tops. A dress of Charles is thus described:—A falling band, green doublet (from the armpits to the shoulders wide and loose), zigzag turned-up ruffles, long green breeches (like a Dutchman's), tied below the knee with yellow ribbons, red stockings, green shoe-roses, and a short red cloak lined with blue, with a star on the shoulder; the king sometimes wore a large cravat, and at other times a long falling band with tassels. The dress of the gay courtiers or cavaliers consisted of a doublet of velvet, silk, or satin, with large loose sleeves, slashed and embroidered; Vandyke collar and band, and short embroidered cloak, worn on one shoulder; the long breeches, fringed and pointed, met the ruffled tops of the boots; the embroidered sword-belt was worn over the right shoulder, and in it was hung a Spanish rapier; and in the flapping beaver hat was worn a plume of feathers confined by a jewel. A buff coat or jerkin was often worn, as a better defence than the doublet, which is sometimes covered. The engraving represents a citizen of this period more plainly attired.

Citizen in the time of Charles I.

The female costume of this period was rather elegant than splendid. Gowns with close bodies and tight sleeves were worn, though the fardingale was retained, with a gorget ruff standing up about the neck like a fan. French hoods were still worn, though with little distinction as to rank. The hair was worn in small curls, and the hoods, of all colours, fastened under the chin with curious effect. Earrings, necklaces, and bracelets were much worn; but the Puritans forbade the females to wear lace, jewels, or even braided hair; and they retained the close hood and high-crowned hat.

Towards the close of the reign of Charles I., the cumbrous fardingale disappeared, with the yellow starched ruff and band. These tasteless fashions having disappeared, the female dress became very elegant, with its rich full skirt and sleeves, and falling collar edged with rich lace, and the hair worn in graceful ringlets; but these vanities were condemned by the Puritan party.

With the Restoration of Charles II. came certain tasteless innovations upon the elegant Vandyke costume of the time of Charles I., which were the first resemblance to the coats and waistcoats of the present day. Thus our most picturesque attire lasted little more than a quarter of a century. Its decline was gradual; its chivalric character soon degenerated into grotesqueness, which in its turn changed to stark meanness. Early in the reign of Charles II., the doublet was much shortened, and worn open in front, where, and at the waistband, the rich shirt was shewn; and the loose sleeves and breeches were decked with ribbons and points, and from the knee-bands hung long lace ruffles. At the wrists, too, ruffles were worn; but the lace collar was shorn of its points, designated to this day Vandyke. The cloak was retained upon the left shoulder, and the high-crowned and plumed hat remained for a short time; but the crown of the hat was soon lowered.

The petticoat breeches were another absurdity; although ornamented with ribbons at the sides, the lining strangely appeared below the breeches, and was tied at the knees; to match which, the sleeves of the doublet only reached to the elbows, and from under them bulged the ruffled sleeves of the shirt, both being ornamented with ribbons. Meanwhile the skirt of the doublet had been lengthened from above the waist nearly to the knees, and had buttons and button-holes in its entire length, thus becoming a *coat*, and so named in an inventory of 1679; wherein also are the items of *waistcoat*, *breeches*, *pantaloons*, *drawers*, and *trousers*, being the earliest mention of these articles. Stockings of various kinds were common; and 'the lower ends of stockings' are understood as socks. Instead of the lace collar was worn the long square-ended cravat, of the same material, from Brussels and Flanders.

The female costume, as if to compensate for the tasteless additions to that of the men, retained much of its elegance in Charles's reign; indeed from this time 'the stronger sex' appear to have left the art of dress to the ladies. The portraits of the beauties of the court of Charles II., in Windsor Castle and Hampton Court Palace, are familiar illustrations, in which we see only a pearl necklace upon the bosom, and the hair falling in luxuriant ringlets from beneath a string of pearls. The gowns are of the richest satin, low in the bosom, and have long trains, so that the wearers could not 'stir to the next room without a page or two to hold them up.' The annexed engraving represents a citizen's wife performing this office herself.

Citizen's wife in the time of Charles II.

Passing to the reigns of James II. and William III., we find few noticeable novelties in costume. The coats were often of velvet, without collars, with large hanging sleeves, and button-holes of gold embroidery. The petticoat breeches were exchanged for the close-fitting garments tied below the knee, and therefore called *knee-breeches;* the broad-brimmed hats were turned up on two sides, and edged with feathers or ribbons; the fashion lay in the rich long lace cravat and embroidered waistcoat; the band was now narrowed, so as to resemble that worn at the present time by clergymen. The periwig was worn still longer than hitherto, hanging down in front, or flowing upon the shoulders, though the colour was altered from black to suit the complexion; and combing these wigs was a piece of gallantry, for which purpose a comb was carried, whence the origin of our present pocket-comb: and at court, in the walks of Kensington, the Mall of St James's, or the boxes of the theatre, the beaux turned their wig-curls over their

fingers whilst in conversation; the effect of these wigs flowing over the cuirass will be seen in the portrait of the great Duke of Marlborough.

The female costume was unchanged in the reign of James II.; but it became less luxuriant and more formal in the time of William and Mary, in accordance with Dutch taste. The waists were much lengthened with velvet stomachers, covered with jewels, so as to conceal the bosom, hitherto unsparingly exposed; the sleeve was made tight, and trimmed with lace lappets or ruffles, and long gloves were worn, so as entirely to cover the arm; but the skirts were worn long, full, and flounced; the hair, instead of flowing in ringlets, was gathered up, and strained over a toupee of silk or cotton wool, carried up so high as to be called a tower, covered with a lace scarf or veil that hung in front below the bosom; but this head-dress gradually shrunk into a caul with two lappets, known as a 'mob.' False locks and curls, set on wires to make them stand out, were also worn. Before the Revolution, the citizens' wives dressed with becoming plainness, and gentlewomen wore serge-gowns, which, after 1688, were rejected by chambermaids.

A few of the fashions and peculiarities of this century may be summed up in conclusion. From the reign of James I., the ladies appear to have dressed their hair in better taste than previously, in curls on each side of the face, and braided in a knot at the back of the head, where it was often ornamented with jewels or pearls, or a single feather. It was next worn in long locks flowing below the shoulders; and the love-lock, ornamented with ribbon and twisted pearls, was worn on one side. From the reign of Charles II. to that of Queen Anne, long hair was much prized, and was often sold by women of inferior fortune to be made into periwigs. About this time the *fontange*, or top-knot, so called from Mademoiselle de Fontange, who first wore it, was driven out of fashion by the fanatical spirit of the time. *Hair-powder* was also introduced from France in this century: it was worn of various colours—an absurdity only discontinued at the close of the last century. Towards the close of the century, wigs became fashionable, together with false hair—'a custom contrary to our forefathers, who wore their own hair.'

Under the House of Stuart, the shoe-rose yielded to the shoe-string, the beaux wearing them of silk tagged with silver, and the humbler classes wore laces of plain silk, or even leather thongs—the latter still to be met with in rural life. Shoe-buckles, in size and shape resembling the horse bean, were introduced at the period of the Revolution.

Eighteenth Century.

In the early part of the eighteenth century, the costume of the English gentry was greatly affected by that introduced into general usage in France by Louis XIV. About the reign of Queen Anne, the new French fashions had been embraced by courtiers, physicians, and other professional persons in England, also the higher order of gentry; and in the following reigns of George I. and II., they became universal.

This dress of the old English gentleman, as it afterwards came to be called, consisted at first, during Queen Anne's reign, of a periwig in formal curls, partly contained in a silk bag on the shoulder; a small cocked-hat, full-bottomed coat, short breeches, blue or scarlet stockings drawn over the knee, and square-toed shoes, with small buckles and high red heels. And this formal costume, relieved only by lace cuffs, ruffles, and neckcloth, and gold or silver clocks in the stockings, remained unmodified through three-quarters of the century. The engraving shews a gentleman of the year 1750, and reminds us that the snuff-box, first carried in the reign of James II., continued indispensable for the 'fine gentleman.' The origin of the cocked-hat is easily explained. The wide flaps or broad brims of the hats in use being found to be inconvenient, they were looped up with a cord and button. At first this was done according to fancy, but latterly there were distinct fashions in cocking the hats. Cocked-hats, richly trimmed with gold-lace and ostrich feathers, occur in Hogarth's pictures, which indeed will furnish a better idea of the entire costume from 1727 to 1760 than many pages of description; and the portraits of Sir Joshua Reynolds will supply the dress of the next forty years.


Gentleman of 1750.

The fashions of wigs were as various as those of hats. A peruke and a plaited and tied tail were called a Ramillies, from the famous battle of that name. The tie-wig became the fashion, from the celebrated Lord Bolingbroke going to court with his wig tied up, upon which Queen Mary observed that he would 'soon come to court in his night-cap'—a royal rebuke which established a fashion. In 1764, wigs went out of wear, and the wig-makers of London petitioned George III. to compel gentlemen to wear wigs by law, for the benefit of their trade! In the present day, formal wigs are almost confined to the heads of prelates and law-officers; and the latter, to get rid of the powder nuisance, wear wigs made of other materials than hair—as the metal platina. Wigs are, however, much worn, from the greater prevalence of baldness than formerly; but their perfection now consists in bearing so close a resemblance to the natural or living hair as to avoid detection.

Towards the middle of the reign of George III., the male dress took the form of the court suit worn at the present day; the breeches having, from the year 1760, been worn over the knees, fastened by buckles or strings. The coats of the eighteenth century were of velvet, silk, or satin, as well as broadcloth, and their colours very fanciful. Hogarth's favourite colour was sky-blue; Reynolds's, deep crimson and violet; and Goldsmith rejoiced in plum-colour. About 1790, cloth became the general wear; the waistcoat being of the costlier materials, and embroidered, and sometimes the breeches. Buckles were worn at the knees and in the shoes till the close of the last century; and the large square plaited buckle was the *ton* until 1791, when shoe-strings became general; though the Prince of Wales and his household endeavoured, by wearing buckles, to retain the fashion.

The female costume of the eighteenth century was as formal and tasteless as that of the men. The most odious piece of attire introduced in the early part of the century was the large whalebone petticoat, which degenerated into the hooped petticoat, and made a lady to appear as if standing in an inverted tub. In the reigns of George I. and II., loose gowns, called *sacques*, and hooded silk cloaks, were worn, and a very small muff, such as have been lately revived. This costume is shewn in the above portrait of a lady of George II.'s time. Ornamental aprons were also worn, as at the present day, with the watch, necklace, and the fan, which was sometimes from


Lady in the time of George II.

twelve to eighteen inches in length, and beautifully made. Gay sings—

> The fan shall flutter in all female hands,
> And various fashions learn from various lands.
> For this shall elephants their ivory shed,
> And polished sticks the waving engines spread:
> His clouded mail the tortoise shall resign,
> And round the rivet pearly circles shine.
> On this shall Indians all their art employ,
> And with bright colours stain the gaudy toy:
> Their pains shall here in wildest fancies flow;
> Their dress, their customs, their religion shew..

Spanish broadcloth, trimmed with gold-lace, was used for ladies' dresses in the reign of George I.; and furbelowed scarfs were worn from the duchess to the peasant.

Veils of the finest material, as a shroud to the female features, are of great antiquity, and may be traced to Oriental nations, among whom the seclusion of women from general gaze is a point of etiquette. In the eighteenth century, in England, after the disuse of towering head-dresses, veils of an elegant fabric were introduced, and still are not altogether out of date. Female caps of gauze or muslin are of French origin, and have always been multifarious in form. The bonnet, in early times generally made of velvet, cloth, and silk, was in the eighteenth century changed to straw. Gay mentions a new straw-hat lined with green, about 1724, but it was then comparatively rare; for the simple art of plaiting straws together to make bonnets was only practised to any considerable extent about sixty years since.

Nineteenth Century.

The formalities of the eighteenth century received a terrible blow at the French Revolution; and in the ten years from 1790 to 1800 a more complete change was effected in dress, by the spontaneous action of the people, than had taken place at any previous period in a century. The change began in France, partly to mark a contempt for old court usages, and partly in imitation of certain classes of persons in England, whose costume the French mistook for that of the nation generally. This new French dress was introduced by the party who were styled the Sans Culottes. It consisted of a round hat, a short coat, a light waistcoat, and pantaloons; a handkerchief was tied loosely round the neck, with the ends long and hanging down, and shewing the shirt collar above; the hair was cut short, without powder, *à la Titus*, and the shoes were tied with strings.

The comparatively simple form of dress of the Sans Culottes found many admirers in England, and soon became common among young men; the change from antique fashions was also greatly helped by the imposition of a tax on the use of hair-powder, which was henceforth generally abandoned. Pantaloons, which fitted closely to the leg, remained in very common use by those persons who had adopted them till about the year 1814, when the wearing of trousers, already introduced into the army, became fashionable. It is proper, however, to mention that trousers had, for the previous fifteen or twenty years, been used by boys, and were perhaps from them adopted by the army. Previous to the French Revolution, the dress of boys was almost the same as that of men. Although trousers were generally worn after 1815, many elderly persons still held out in knee-breeches against all innovations, and till the present day an aged gentleman may occasionally be seen clinging to this eighteenth-century piece of dress. The general use of white neckcloths continued, notwithstanding the introduction of the standing collar, till the reign of George IV., when this monarch's taste for wearing a black silk kerchief or stock, and also the use of black stocks in the army, caused a remarkably quick abandonment of white neckcloths, and the adoption of black instead. The year 1825, or thereabouts, was the era of this signal improvement in costume.

While these leading changes were effecting, other alterations of a less conspicuous nature were from time to time taking place. The disbanding of the army after the peace of 1815 led to various transformations besides those we have mentioned. While pantaloons were the fashionable dress, it became customary to wear Hessian boots; these, which had originated among the Hessian troops, were without tops, and were worn with small silk tassels dangling from a cut in front; being drawn over the lower part of the pantaloons, they had a neat appearance; but the keeping of them clean formed a torment that prevented their universal use. When trousers were introduced from the practice of the army, the use of Wellington boots to go beneath them also became common.

Referring to the era of 1815 to 1825 as that in which trousers, Wellington boots, and black neckcloths or stocks came into vogue, we may place the introduction of the surtout in the same period of history. From the time when the collarless and broad-skirted coat had disappeared about the commencement of the century, the fashion of coats had changed in various ways till the above-named era, when the loose frock-coat or surtout was added to the list of garments. We remember seeing French military officers, when in undress, wearing frock-coats as early as 1811; it is probable, therefore, that the modern surtout is only a variety of the loose military great-coat brought from the continent by the British army; however it originated, it may be allowed to be one of the greatest improvements in the style of dress which has yet occurred in the nineteenth century.

On the whole, the dress of the current age is characterised by simplicity and elegance. The male attire is plain, and in good taste, with the exception of the 'dress-coat' and hat, both of which are as unnatural in cut as they are void of comfort. Female attire was never perhaps more chaste and becoming; the chief article which occasionally merits censure being the ever-changing but never very classic-looking bonnet. And yet, though convinced of an occasional absurdity in the matter of costume, it is the wiser course rather in so far to follow than attempt to lead in an altogether different direction. 'A man,' says Feltham, and he says wisely, 'ought, in his clothes, to conform something to those that he converses with, to the custom of the nation, and the fashion that is decent and general, to the occasion and to his own condition; for that is best that best suits with one's calling and the rank we live in. And seeing that all men are not Œdipuses, to read the riddle of another man's inside, and that most men judge by appearances, it behoves a man to barter for a good esteem, even from his clothes and outside. We guess the goodness of the pasture by the mantle we see it wears.'

PROVINCIAL PECULIARITIES.

The *Welsh*, as a relic of an ancient Celtic people, possess remarkably few external traits of their original. They have, like the Irish, become Anglicised in costume, and we should in vain search amongst them for the *breacan*, or checkered clothing, of their Celtic ancestry. The most remarkable part of the Welsh costume is the hat worn by the women. All females in parts of the country not modernised wear round black hats, like those of men; and this fashion is supported to a small extent by ladies of the higher rank. This use of the hat is not Celtic; the fashion is derived from England, and is only two or three centuries old.

The *Irish* at an early period wore the same Celtic fashion of attire as was preserved till recent times in the Scottish Highlands; but, as in Wales, everything of the kind disappeared as the country became Anglicised. A primitive species of attire, including coloured mantles, kirtles, and other fanciful garments, remained in use

till the sixteenth century, when laws were passed by Henry VIII., enjoining the use of caps, cloaks, coats, doublets, and hose of English cut, but of Irish or any other materials. The general dress in Ireland, at the present day, rarely varies from that in England. There are, however, some interesting peculiarities of costume amongst the peasantry of the southern and western counties.

The costume of the Lowland Scotch has generally resembled that of the English in all its changes and vicissitudes. At the present day, Scotland cannot be said to possess any national costume which distinguishes the bulk of the people from their fellow-subjects in South Britain; and however much the fact may surprise the artists and dramatists of England, it is very certain that the inhabitants of Edinburgh, Glasgow, and other cities and towns of Scotland, are dressed in precisely the same fashion of garments as is now seen in the streets of London, Paris, Brussels, or the capital of any other civilised country.

Anciently, the dress of the Scotch, both those of the Highlands and Lowlands, was distinguished by party-colours, woven in checks, according to taste or ancient usage. By the Celtic race in the Highlands, this species of variegating cloth with colours was called *Breacan*, which signifies spotted; and by the Teutonic population of the Lowlands it received the name of *Tartan*, a word whose origin has defied the researches of etymologists, but which it is not unlikely may have been derived from the ancient Tatar races, who used a similar kind of colouring in their attire. Till the present day, cloths checked in various colours are worn by the Calmucs and other tribes in the north of Europe. Tartan for clothing disappeared in the Lowlands of Scotland in the course of the seventeenth century; but even as late as the beginning of the eighteenth century, party-coloured plaids were pretty generally worn; and young women were in the habit of using a 'tartan screen'—that is, a small plaid of variegated colours. The tartan screen, which was worn in the fashion of a covering for the head and shoulders, so as to combine in some measure the properties of a modern bonnet and shawl, was formed of costly materials; the ladies of the higher classes employing silk, and those of inferior station fine worsted, the colours in each case being remarkably brilliant. Being often employed with a degree of real or affected modesty to conceal a part of the features, it may be said to have performed the office of a veil to Scottish maidens; and hence its appellation of *screen*. Perhaps the use of this species of coif was a consequence of a point of etiquette, which rendered it indecorous for young unmarried women to wear any regular garment on the head.

While tartan disappeared from the Lowlands, except in the screens of the women and the plaids of the shepherds, it continued to be in universal use in the Highlands, where it may be said to have been always associated with the manners of the people; and this leads us to say a few words respecting

Highland Costume.—Originally, the costume of the Highlanders resembled that of other Celtic tribes, and consisted of little else than a woollen garment of variegated colours, wrapped round the body and loins, with a portion hanging down to cover the upper part of the legs. In progress of time this rude fashion was superseded by a distinct piece of cloth forming a philibeg or kilt, while another piece was thrown loosely as a mantle or plaid over the body and shoulders. In either case, the cloth was variegated in conformity with the prescribed *breacan*, or symbol of the clan; and hence the tartan was sometimes called *cath-dath*, or battle-colours, in token of forming a distinction of clans in the field of battle.

According to the author of the *Vestiarium Scoticum*, the following, in the reign of James VI., was the list of chief and subordinate clans, each possessing its own tartan; among these clans, it will be observed, are included certain Lowland families or houses, who had also adopted the same kind of cognizance:—

Clan Stewart—six colours, chiefly red, checked with green, purple, black, white, and yellow.
Prince of Rothsay—three colours, checked with green and white.
Royal Stewart—chiefly white, checked with green, red, purple, and black.
Macdonald of the Isles—chiefly green, checked with black, purple, red, and white.
Ranald—chiefly green, checked with black, purple, red, and white.
Macgregor—chiefly red, checked with green and white.
Ross—chiefly red, checked with green and purple.
Macduff—chiefly red, checked with green, black, and purple.
Macpherson—equal portions of black and white, with small lines of red and yellow.
Grant—chiefly red, with checks of green and purple.
Monro—chiefly red, checked with black and white.
Macleod—chiefly yellow, checked with black and red.
Campbell—chiefly green, checked with black, purple, yellow, and white.
Sutherland—chiefly green, with black, purple, red, and white.
Cameron—chiefly red, checked with green and yellow.
Macneil—chiefly green, with purple, black, white, and red.
Macfarlane—very dark, being chiefly black, checked with white.
Maclachlan—chiefly yellow, with checks of brown.
Gillean or Maclean—chiefly green, checked with black and white.
Mackenzie—nearly equal portions of green and purple, checked with black, white, and red.
Fraser—chiefly red, checked with purple, green, and white.
Menzies—equal portions of red and white.
Chisholm—chiefly red, checked with purple, green, and white.
Buchanan—chiefly red and white, with small black stripes.
Lamont—chiefly green, checked with black, purple, and white.
Macdougall—chiefly red, checked with black, purple, and green.
Mackintyre—chiefly green, checked with purple, red, and white.
Robertson—chiefly red, checked with purple and green.
Macnab—chiefly red, checked with crimson, green, and black.
Mackinnon—chiefly red, checked with green, black, and white.
Mackintosh—chiefly red, checked with green, black, and white.
Farquharson—chiefly green, with purple, black, red, and yellow.
Gun—chiefly green, checked with black and red.
Macarthur—chiefly green, checked with black and yellow.
Mackay—chiefly a bluish purple, with black and red checks.
Macqueen—nearly equal portions of red and black, with yellow.
Bruce—chiefly red, with green, yellow, and white.
Douglas—very dark, being equal checks of black and slate colour.
Crawford—equal portions of red and green, with white.
Ruthven—chiefly red, with purple and green.
Montgomery—chiefly light green, checked with purple.
Hamilton—chiefly red, with purple and white.
Wemyss—chiefly red, checked with black, white, and green.
Comyn—chiefly red, with green, black, and white.
Sinclair—chiefly green, checked with black, purple, red, and white.
Dunbar—chiefly red, checked with green and black.
Leslie—chiefly red, checked with purple, black, and yellow.
Lauder—chiefly green, with purple, black, and red.
Cunningham—chiefly red, with black, purple, and white.
Lindsay—chiefly red, with purple and green.
Hay—chiefly red, with green, yellow, white, and black.
Dundas—chiefly green, with purple, black, and red.
Ogilvie—chiefly green, beautifully checked with purple, black, yellow, and red.
Oliphant—equal portions of green and purple, with black and white.
Seton—chiefly red, with small lines of green, black, purple, and white.
Ramsay—chiefly red, with black squares checked with white.
Erskine—red and green.
Wallace—red and black, checked with yellow.

Brodie—chiefly red, with black and yellow.
Barclay—chiefly light green and purple, checked with red.
Murray—chiefly green, checked with black, purple, and red.
Urquhart—chiefly green, with black, purple, white, and red.
Rose—chiefly red, with small checks of purple, green, and white.
Colquhoun—green, purple, black, red, and white.
Drummond—chiefly red, with green and dark red.
Forbes—chiefly green, with black, red, and yellow.
Scott—chiefly red, with green, red, and black.
Armstrong—chiefly green, with black, purple, and red.
Gordon—chiefly green, with purple, black, and yellow.
Cranstoun—yellowish green, with purple and red.
Graham—chiefly green, with black checks.
Maxwell—chiefly red, with green and black.
Home—dark purple, with black, red, and green.
Johnston—chiefly green, with purple, black, and yellow.
Ker—chiefly red, with black and green.

In 1747, with the view of breaking the spirit of the clans, a law was enacted proscribing the use of the Highland dress, including the tartan in all its varieties. The following is the provision in the act of parliament on the subject:—'That from and after the 1st day of August 1747, no man nor boy, within that part of Great Britain called Scotland, other than such as shall be employed as officers and soldiers in his majesty's forces, shall, on any pretence whatever, wear or put on the clothes commonly called Highland clothes—that is to say, the plaid, philibeg or little kilt, trowse, shoulder-belts, or any part whatsoever of what peculiarly belongs to the Highland garb; and that no tartan or party-coloured plaid or stuff shall be used for great-coats or for upper-coats; every person offending, being convicted by the oath of one or more credible witnesses before any court of justiciary, "shall suffer imprisonment, without bail, during the space of six months;" and being convicted for a second offence, shall be transported to any of his majesty's plantations beyond seas, there to remain the space of seven years.' This contemptible law was repealed in the year 1782; but before that time the tartan and the 'garb of old Gaul' had been generally abandoned, except among Highland regiments, and it is chiefly copies from their attire that have guided modern attempts at reviving the costume.

As modernised and improved by the Highland regiments, the 'belted plaid,' worn as the philibeg or small kilt, with a separate drapery depending from the shoulder in imitation of the ancient garb, is one of the most picturesque and graceful costumes to be seen in any part of the world; and although it leaves the legs bare at and a short way above the knee, we are assured that it is by no means too meagre an attire for cold weather. Anciently, the Gael wore no shoes or garments for the legs. The feet were only on occasions covered with pieces of hide, tied with a thong, called *brogs*, which, though slender, were very lasting, and were well suited for walking or running on heathy mountains. The introduction of shoes, and also hose, formed from the same tartan cloth as the kilt, is comparatively modern. The hose of the common men in the Highland regiments are still not knitted or woven like stockings, but cut from the web and sewed. It appears that even in ancient times the Celtic tribes did not always wear the loose garments we have described; but that they also, or at least some of them, wore the *triughas* or *trius*, a species of vestment 'formed of tartan cloth, nicely fitted to the shape, and fringed down the leg.'

The coat, in which the upper part of the body and arms of the Highlanders are now invested, is of course quite modern, having come into use when the old form of the plaid dress was laid aside. Made, as it usually is, with short skirts and small round buttons, it cannot be considered in harmony with the rest of the attire; but it is nevertheless convenient.

The bonnet has for ages been a part of the Highland costume, as it was formerly also of the Lowlanders, and of the English, previous to the introduction of felt hats. The English gave up bonnets sooner than the Scotch; and ultimately the cry that 'the blue bonnets had come over the Border,' was equivalent to saying that a party of Scotch marauders had entered England on one of their usual hostile excursions. The Highlanders, with whom the bonnet has remained longest as a part of ordinary

Highlander.

dress, have adopted very many shapes and modes of ornamenting their headgear. The heavy plume of black feathers used in the army is quite modern, and in exceedingly bad taste, besides being totally unconformable to the idea of a primitive and light costume. The true bonnet of the Highlands is small, either round or peaked in front, dark-blue or gray in colour, and without any tartan or checkering. In fancy dress, however, the bonnet is somewhat larger, and occasionally has a band of tartan. Highland chiefs were distinguished by three pinion feathers of the native eagle stuck in the bonnet; and those who enjoyed the rank of gentlemen were entitled to wear a single feather. It was customary also for the members of each clan to wear in the bonnet a peculiar badge formed of some native shrub. Authorities differ as to the precise shrubs worn for this purpose. The Buchanans used a sprig of bilberry; the Camerons, crowberry; the Campbells, fir-club-moss; the Forbeses, broom; Frasers, yew; &c.

The full dress of Highland chiefs and gentlemen has always been liberally ornamented with sword, baldrick, dirk, skean-dhu (worn in the stocking) large brooches, buckles, shot-pouch, and purse. The purse or sporan is a most important part of the costume; it is formed of the skin of a wild animal with the hair on, and tied to the waist by a band, hangs down in front, so as to fall easily upon the lap, and not incommode the legs in walking. It is usually ornamented with silver tags and tassels, and a flap covering the mouth of the purse is sometimes decorated with the vizard of a fox.

After a period of indifference to the preservation of the Highland dress, a revival of the national tone of feeling respecting it has been for some time apparent. At the same time, it is employed only as a fancy costume on festive or gala occasions; and in the Highlands, the ordinary dress of the English is in common use.

INDEX, AND GLOSSARY OF TERMS.

*** The Figures in the columns indicate the pages of the Text in which the particular term or subject is fully explained.

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